

Exceptions vs. Non-exceptions in Sound Changes: Morphological Condition and Frequency

LIU Sha

Fukuoka University, Japan

liusha@fukuoka-u.ac.jp

Abstract

This paper takes an approach different from most previous studies by firstly comparing exceptions with non-exceptions in the diphthongization of [i] to [ei] in Mandarin (AD 1324–Present) to locate factors that explain exceptions. Then it focuses solely on non-exceptional morphemes in this process by comparing morphemes at the forefront of this process with those undergoing it later to examine factors to explain morphemes leading this sound change. Statistical analysis shows that morphemes with the highest frequency among all related morphemes tend to be exceptions to diphthongization of [i] to [ei], and morphemes with high frequency among those non-exceptional morphemes tend to undergo this process earlier. In addition, the factor of frequency change, a proposal of this paper, is statistically significantly correlated with morphemes that lead diphthongization. The morphological condition has been rejected as statistically significant both for explaining exceptions to sound change and leading morphemes in sound change.

Keywords: diphthongization, leading morphemes, frequency, frequency change, exceptions

Povzetek

Članek uporablja nekoliko drugačen pristop v primerjavi z večino prejšnjih študij; najprej primerja izjeme z neizjemami pri diftongizaciji [i] v [ei] v mandarinščini (1324 AD–danes) z namenom poiskati dejavnike za razlago izjem. Nato se osredotoči izključno na neobičajne morfeme v tem procesu s primerjavo morfemov, ki so vodilni v spremembi, in morfemov, ki so spremembam podvrženi relativno pozno. Na ta način preučimo dejavnike in okolja, ki spodbujajo diftongizacijo [i] v [ei]. Rezultati statističnih analiz kažejo, da so morfemi z najvišjo pojavnostjo med vsemi sorodnimi morfemi ponavadi izjeme pri diftongizaciji [i] v [ei], morfemi z visoko pojavnostjo med temi neobičajnimi morfemi pa so ponavadi podvrženi temu procesu prej. Poleg tega je dejavnik sprememb pojavnosti, ki je predlog tega prispevka, statistično značilno povezan z morfemi, ki so vodilni pri diftongizaciji. Morfološki pogoj je bil zavrnjen kot statistično pomemben tako za razlago izjem pri glasovni spremembi kot tudi za vodilne morfeme v obravnavani glasovni spremembi.

Ključne besede: diftongizacija, vodilni morfemi, pojavnost, sprememba pojavnosti, izjeme



1 Introduction

Previous studies have proposed morphological conditions and frequency to account for exceptions to sound change, and morphemes that are at the forefront of sound change (see e.g., Grimm, 1822; Postal, 1968; King, 1969; Antilla, 1972; Melchert, 1975; Vincent, 1978; Guy, 1991a; Pintzuk, 1991; Santorini, 1992, 1993; Kroch, 1994; Donohue, 2005; Bermúdez-Otero, 2007). However, disagreements concerning the role of the two mentioned factors in sound change are not rare. Although Postal (1968) and King (1969), among others, claim that the morphological condition has a role in sound change, Renwick et al. (2014) state that their results show little support for such a claim. Even scholars who claim that the morphological condition has a role in sound change cannot agree on its exact role: some claim that bound morphemes lead sound change, while others claim that it is free morphemes that lead it. Arguments concerning the frequency factor and sound change are more complex. A long-standing debate exists between authors claiming that the frequency factor takes a part in sound change and others claiming that sound change is independent of any frequency effects. The debate is further complicated by the fact that even authors who claim that frequency has a role in sound change cannot agree with each other on its exact role: some suggest that high-frequency morphemes lead sound change, while others argue that low-frequency morphemes are at the forefront of sound change, and yet there are those who claim that either high-frequency morphemes or low-frequency morphemes are the ones that lead sound change.

In addition to the debate presented above, the present study notices another problem: scholars use different types of data to probe into the role of morphological condition and frequency in sound change. Some scholars compare exceptions and non-exceptions in a sound change process, while others compare morphemes that undergo a sound change process earlier with morphemes that undergo the same sound change later. This may be the reason that different scholars arrive at different conclusions: they had focused on different phases of sound change. This prompted the present study to inspect a sound change process from two aspects: (1) exceptions and non-exceptions in this sound change, and (2) morphemes that lead this sound change and morphemes that undergo it later. The paper firstly compares exceptions with non-exceptions in this sound change process to locate factors to explain exceptions in sound change. Then the paper compares morphemes that were at the forefront of this sound change with morphemes that underwent it later to locate factors to account for morphemes leading this sound change.

This paper takes the diphthongization of [i] to [ei] in Mandarin (AD 1324–Present) as its data source. What makes data from Chinese interesting is that Chinese is a language with a long history and thus can provide various kinds of data for sound change discussion. In addition, not much attention has been paid to Chinese in sound change study (see e.g., Wang, 1969; Chen and Wang, 1975). Previous studies mainly

take languages in the Indo-European language family as their focus. Since the sound change mechanism is supposed to be universal, it appears reasonable and necessary to examine data from languages belonging to various language families. In this respect, Mandarin is a good candidate since it belongs to the Sino-Tibetan language family and has not been widely discussed. Diphthongization of [i] to [ei] is a sound change process with exceptions that can provide data serving the proposal of the present study. Further, diphthongization of long high vowels is common in the world's languages and thus possible to be compared with parallel processes in other languages.

This paper is structured as follows. Section 2 discusses factors in the sound change in previous studies and presents a new proposal. Section 3 briefly sketches diphthongization of [i] to [ei] in Mandarin (AD 1324–Present). Section 4 carries out statistical analysis to locate factors to explain exceptions to the diphthongization of [i] to [ei] in Mandarin. Section 5 carries out another statistical analysis to examine factors to explain the morphemes leading this process. Section 6 puts forward some conclusions and issues relating to future research.

2 Previous studies

Previous studies explain exceptions to sound change in terms of various factors. Among them, morphological condition and frequency are the two most debated (see e.g., Chafe, 1968; King, 1969; Postal, 1968; Antilla, 1972; Campbell, 1974). In this section, the paper firstly reviews the two factors and disagreements concerning them, and then gives its own proposal.

2.1 Morphological condition

Postal (1968) and King (1969) can take the credit for noticing the possible role of morphological conditions in sound change although their claims have been questioned from many perspectives without resolution (Melchert, 1975). Following them, Zwicky (1970) discusses the auxiliary reduction in English. He (1970) notices that the rule which renders [i:y e:y u:w] to [i e u] and [a:y a:w] to [ay aw] applies only to pronominal forms ending in vowels (e.g., he, me, who) and followed by a contracted auxiliary other than [z]. A few years later, Rochet (1974) considers the change eN > aN in Old French and claims that this process was initiated as a morphological conditioned change. Malkiel (1976) discusses the diphthongizations in late Old Spanish, *ié* > *i* and *ué* > *e*, and argues that a set of morphological conditions can explain this phenomenon better than phonological conditions (see also Cerrón-Palomino, 1974; Johnson, 1982).

2.1.1 Exceptions vs. non-exceptions

Postal (1968, p. 247) focuses on Mohawk, the language spoken by Mohawk people, and notices that [e] is regularly inserted into [kw] sequences except when the [k] is “the first person morpheme and the [w] the first element of the plural morpheme.” In his view (1968, p. 240), this language example shows that “nonphonetic morphophonemic and/or superficial grammatical structure” could also condition sound change (reviewed in Fudge, 1972; see also King, 1969). King (1969) is concerned with the final schwa deletion in Yiddish. According to him (1969), this rule does not apply when the final schwa is in an adjective inflectional ending. King (1969) concludes that this is evidence of morphologically conditioned sound change (reviewed in Robinson and van Coetsem, 1973; see also Antilla, 1972). Vincent (1978, p. 420) refers to the word-final schwa deletion in Spanish, and points out that the word-final schwa following a VC sequence is dropped, except in “the first person singular preterite of a number of irregular verbs ..., the third person singular present indicative of all second and third conjugation verbs ..., and the first and third singular present subjunctive of all first conjugation verbs.” Morphological conditions in King (1969) and Vincent (1978) are concerned with word class in a rough term: King (1969) is concerned with adjectives and Vincent (1978) is concerned with verbs. More recently, Crowley (1997, p. 243) focuses on Southern Paamese and Northern Paamese, two languages of Central Vanuatu, and reports “a correspondence of Southern Paamese /l/ to Northern Paamese /i/, /l/, or zero” in all word classes except verbs. According to Crowley (1997, p. 244), this is “a clear example of a sound change that does not involve purely phonological conditioning factors, but also ... grammatical conditioning.” More specifically, this example shows that at least some sound changes apply only in some word classes (Crowley, 1997).

What complicates the picture is that some scholars claim that it is morphosyntactic structure, instead of word class, that can explain exceptions to sound change. Donohue (2005) uses the voicing of voiceless stops in Palu’e to show that morphological conditions can explain exceptions to this sound change: bound grammatical morphemes seem to have fewer exceptions than free lexemes. Donohue (2005, p. 441) goes on with sound changes in Modern Indonesian and Bali-Vitu (Austronesian, Oceanic) to further support his claim, and concludes that sound change “depends as much on morphosyntactic information as it does on ... phonotactic constraints, (phonological) conditioning environments, or changes in related sounds” Bybee (2002) focuses on word-final /t, d/ deletion in American English and concludes that bound morphemes can affect the deletion process. Guy (1991b, p. 2) also focuses on word-final /t, d/ deletion in American English and gives a more detailed conclusion: “underived or monomorphemic words such as *mist*, *pact*, undergo deletion at a higher rate than inflected forms such as past tense verbs like *missed*, *packed*” (see also Labov et al., 1968; Fasold, 1972; Guy, 1991a). Baranowski and Turton (2020) report a result similar to Guy (1991b) for word-final /t, d/ deletion in British English.

It is at this point important to point out that although all scholars referred to in this subsection claim that morphological condition has a role in explaining exceptions to sound change, they hold different views concerning its exact effect. To exemplify, although Crowley (1997) claims that word class can explain exceptions to sound change, Donohue (2005) suggests that morphosyntactic structure, that is the distinction between free morpheme and bound morpheme, is more correlated with exceptions to sound change.

2.1.2 Early application vs. late application

This subsection gives its attention to morphological conditions and non-exceptions in sound change. *Early application* and *late application* mean that morphemes do not undergo a sound change simultaneously: some morphemes undergo it earlier and some morphemes undergo it later. Phillips (1983, 2001, 2006) accounts for this from the perspective of morphological conditions and classifies words into two categories, function words and content words. Function words refer to a wide range of words that normally receive low sentence stress, such as adverbial conjunctions, auxiliary verbs, determiners, prepositions, quantifiers, and so on. Content words mainly include adjectives, adverbs, nouns, verbs, etc. Phillips (1983, 2006) gives an example of strengthening sound change, the change from /d/ to /t/ in Old High German Isidor, and points out that it affected function words last. He (1983, 2006) thus concludes that content words tend to be affected by strengthening sound changes first and function words by weakening sound changes first. Donohue (2005) also tries to explain morphemes leading sound change from the perspective of a morphological condition, but his approach is completely different from that of Phillips (1983, 2001, 2006): Donohue (2005) examines the voicing of voiceless stops in Palu'e and shows that free morphemes tend to lead sound change and bound morphemes follow. Similar to the previous section, disputes are over whether word class or morphosyntactic structure can explain morphemes leading sound change.

2.1.3 Disputes over morphological conditions

Though intriguing, the role of morphological conditions in sound change has been challenged by scholars like Jasanoff (1971), Blevins and Lynch (2009), Brown (2013), and so on. Jasanoff (1971) states that what appears to be morphologically conditioned is in fact regular sound change partially obscured by analogy. Blevins and Lynch (2009, p. 111) claim that the sound change discussed in Crowley (1997) applies to all word classes including verbs, but “phonological and morphological aspects of verbal inflectional paradigms” restore the change in verbs later and give rise to “the apparent exceptionality.” Renwick et al. (2014) also focus on word-final /t, d/ deletion in British English as Guy (1991b) and Baranowski and Turton (2020), but they (2014) claim that their results show little support for the role of any specific morphological condition.

What is most surprising is that completely opposite conclusions concerning the role of morphological conditions have been drawn from the same phenomenon, word-final /t, d/ deletion in British English.

At the same time, some scholars adopt the middle way by claiming that no conclusion can be drawn yet and further investigation is necessary (Sihler, 2000; Campbell, 2013; Manker, 2015). For example, although Manker (2015, p. 287) states that many examples in Phillips (2006) are “actually ... influenced by the ‘most common phonetic environment’ where certain word classes happen to be used in the favorable phonetic environment for the change more often,” Manker (2015) does not give any clear cut answers to this issue. Instead, he (2015) suggests that the possibility of sound changes influenced by morphological factors cannot be absolutely ruled out and needs further extensive investigation, a view in line with Sihler (2000), Campbell (2013), etc.

To sum up, controversies concerning the morphological condition are twofold. The first controversy is whether it has a role in explaining exceptions to sound change and leading morphemes in sound change. The second one is whether word class or morphosyntactic structure can account for exceptions and leading morphemes.

2.2 Frequency

Morphological conditions are not the only factor put forward in previous studies. The frequency factor is perhaps the most widely argued: a long-standing debate exists between scholars claiming that frequency is relevant and others claiming that it is not. What is interesting is that more than a century has passed, and yet there has not been consensus on the frequency effect, and so it is still not well understood. In what follows, this subsection first reviews the frequency effect and exceptions to sound change in previous studies, then reviews the frequency effect and leading morphemes in sound change, and finally reviews disputes over the frequency effect.

2.2.1 Exceptions vs. non-exceptions

The frequency effect has been brought to view since the 19th century. Grimm (1822) discusses the relationship between high-frequency auxiliary verbs and their irregularity. Thomsen (1879) gives a few frequent Romanic verbs and the fact that they are exceptions to normal phonetic development. Jespersen ([1922] 2007, p. 267) more plainly expresses Thomsen’s (1879) ideas in English as “words which from their frequent employment are exposed to far more violent changes than other words, and therefore to some extent follow paths of their own.” Vilhelm Thomsen himself gives a similar explanation in his work (Thomsen, 1920). More recently, Labov (1989, p. 44) focuses on Philadelphia a-tensing and reports that “the most common words ... show the least tendency to shift to the tense class.” Bermúdez-Otero (2007, p. 512) also states that “the words with the very highest token frequency may exceptionally

withstand the change.” Another related research includes Van Bergem (1995). He (1995) discovers that frequency influences the reduction of a pre-stressed vowel in Dutch: the high-frequency words, such as *minuut* (‘minute’), *vakantie* (‘holiday’), and *patat* (‘chips’), are more likely to have a schwa in the first syllable than the phonetically identical low-frequency terms, e.g., *miniem* (‘marginal’), *patent* (‘patent’), *vakante* (‘vacant’). Fidelholtz (1975) reports a similar tendency for the reduction of pre-stressed vowels in English words.

In contrast, other studies suggest that low-frequency words tend to be exceptions to sound change. To exemplify, Bybee (2002) studies the deletion of word-final /t/ and /d/ in American English and finds that the deletion rates in low-frequency words are statistically lower than in high-frequency words. Coetzee and Kawahara (2013, p. 62) observe two language phenomena, English *t/d*-deletion and geminate devoicing in Japanese loanwords, and argue that “*t/d*-deletion usually applies at higher rates to words of higher frequency,” and frequency and rate of Japanese geminate devoicing are positively correlated.

2.2.2 Early application vs. late application

Concerning the frequency effect and leading words in sound change, Hooper (1976) focuses on schwa deletion in English and concludes that frequent words tend to lead this change. Furthermore, Hay and Foulkes (2016) focus on the ongoing change in the pronunciation of word-medial intervocalic /t/ in New Zealand English and report that frequent words lead this change (see also Pierrehumbert, 2001; Duncan, 2011).

Not all scholars hold a similar view. To name a few, Hay et al. (2015, p. 83) conclude the study of regular pronunciation changes in New Zealand English over a 130-year period with the expression that “low-frequency words were at the forefront of ... changes and higher frequency words lagged behind.”

A further dimension of debate is that some scholars claim that different sound changes are led by words of different frequencies. Phillips (1984, 2001, 2006) states that the most frequent words lead sound changes motivated by physiological factors, such as vowel reduction, deletion, assimilation, etc., while the least frequent words lead sound changes that arise from phonological segmental and sequential constraints of the language, such as unrounding in Middle English, diatone formation in Modern English, and others (see also Ogura, 2012).

2.2.3 Disputes over the frequency factor

Fruehwald et al. (2013) express their doubt concerning the role of frequency in sound change. They (2013, p. 219) focus on the Middle High German final stop fortition and claim that this change progresses “in frequency in every context at the same rate over time,” the so-called *constant rate effect* (see also Kroch, 1989, 1994; Pintzuk, 1991;

Santorini, 1992, 1993; Dinkin, 2008). Other scholars more plainly claim that sound change is independent of frequency effects. For example, Zellou and Tamminga (2014, p. 18) study the co-articulatory vowel nasality in Philadelphia English and conclude that “the changes in nasality are independent of an observed frequency effect.” Similarly, Labov (2010) examines the role of frequency in several different phonetically gradual changes and gives the conclusion that the role of frequency is minimal, even if not zero, a view agreed on by Kiparsky (2014). Attention has also been paid to language processes which have been used to support the role of frequency in sound change. To exemplify, word-final /t, d/ deletion in American English is used by Bybee (2002) to argue for the role of frequency in sound change as noted in Section 2.2.1. Walker (2012) focuses on word-final /t, d/ deletion in Canadian English, and reports that his initial results show the correlation between frequency and deletion. However, he (2012) further states that only phonological and morphological factor groups have emerged as statistically significant after he considered more factor groups. Abramowicz (2007) suggests that since scholars like Bybee (2002) and Phillips (1983, 2006) have used the variation word-final /t, d/ deletion in English to argue for the role of frequency, it is reasonable to expect the variable *ing*, that is *g*-dropping as in *walkin’* or *livin’*, to show similar effects in terms of frequency. However, Abramowicz (2007) concludes that his study does not show much frequency effect. Tamminga (2014, p. 457) argues against the frequency effect from another perspective: he questions the legitimacy of using word-final /t, d/ deletion in English to discuss the role of frequency in sound change since “[t]here has never been any evidence ... that coronal stop deletion is a change in progress in any North American dialect.” In other words, Tamminga (2014, p. 457) claims that the data of word-final /t, d/ deletion in English are “stable variation,” but they have been used as evidence for “change in progress.” Tamminga (2014, p. 458) further explores the adjective, conjunction, discourse marker, and preposition forms of *like* and claims that “frequency effects fail to arise.”

2.3 Present study proposal

In sum, disputes in previous studies involve the following two questions. (1) Can morphological conditions and frequency account for exceptions to sound change? (2) Can morphological conditions and frequency account for words leading sound change? If answers to the above two questions are *yes*, then the following two questions should also be brought forward. (1) In terms of morphological condition, does word class or morphosyntactic structure have a role in sound change? (2) In terms of frequency, do high-frequency words or low-frequency words carry the tendency to be exceptions to sound change, and also, do they tend to lead sound change? To answer all these questions, the present study proceeds step by step; it first compares exceptions with non-exceptions in the diphthongization of [i] to [ei] in Mandarin and then compares words that have led this process with words that have undergone it

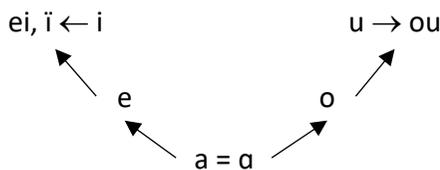
later. A comparison between exceptions and non-exceptions by the use of statistical analysis may present hints concerning factors to explain exceptions to sound change. A statistical analysis of words leading sound change with those undergoing it later may present factors correlated with words at the forefront of sound change.

In addition, the present paper notices a factor that awaits exploration about its role in sound change: previous studies have made little reference to the frequency change factor. The frequency change is calculated by the subtraction of the frequency of a word in the time concerned with the frequency of the same word in an earlier period. If the frequency factor is correlated with sound change, the frequency change factor may also be associated with sound change. To exemplify, Pierrehumbert (2001), Duncan (2011), among others claim that sound change usually affects the most frequent lexical items first. Following their logic, lexical items with increased frequency seem more likely to lead a certain sound change than lexical items with decreased frequency, since lexical items with increased frequency are more active and more accessible to a related sound change than lexical items with decreased frequency. In sum, this paper supposes that the frequency change factor also constitutes a desideratum for research.

3 Diphthongization of [i] to [ei] in Mandarin

This paper takes the diphthongization of [i] to [ei] in historical Chinese as its language sample. The diphthongization is a part of the Middle Chinese Great Vowel Shift (Chen 1976, Li 1999), which began no later than the end of the 16th century and finished no later than the beginning of the 19th century (Trigault, [1626] 1957; Edkins, 1857; Luo, 2008). Chart (1) graphically presents the Middle Chinese Great Vowel Shift (Chen, 1976; Li, 1999)

(1) The Middle Chinese Great Vowel Shift (Chen, 1976, p. 195)



According to Chart (1), the general upward movement pushed the original high vowels *i and *u to undergo diphthongization and “became /əi/ and /əu/ respectively.... Eventually, /əi/ and /əu/ emerged as [ei] and [ou]” (Chen, 1976, p. 194). Due to the limited space, the present paper exclusively focuses on *i. The diphthongization of [i]

to [ei] applied with certain conditions. However, diphthongization was “exceptionless with regard to” [i] in the syllables [-ui], [vi], and [fi] in Middle Chinese (AD 601–AD 1336) according to Chen (1976, p. 200). The consonant [v] gradually turned to [u] in the Ming dynasty (1368–1644), almost simultaneously with diphthongization of [i] to [ei] (Luo, 2008). As a result, the three syllables [-ui], [vi], and [fi] in Middle Chinese were “obligatorily realized as [-uei] and [fei] respectively” in Mandarin (AD 1324–Present) (Chen, 1976, p. 200). In other words, the syllables [-ui], [vi], and [fi] are not in the Mandarin syllable inventory. The condition was more complex with [i] in the syllables [bi], [mi], [pi], and [p^hi] in Middle Chinese (Chen, 1976). Here are some related examples.

Table 1: Diphthongization of [i] to [ei] in Mandarin (Baxter & Sagart, 2014)

Middle Chinese (AD 601–AD 1336)	Mandarin (AD 1324–Present)	Gloss
[fi]	[fei]	非 ‘not’
[gwijH]	[k _u eɪ̯]	柜 ‘box’
[pjie]	[pei]	卑 ‘low, humble’
[pjij]	[pi]	庇 ‘cover, protect’
[mijH]	[mei]	媚 ‘love, flatter’
[mij]	[mi]	麋 ‘a kind of deer’

Historical Chinese is usually divided into the following three phases: Old Chinese (1250 BC–AD 600), Middle Chinese (AD 601–AD 1336), and Mandarin (AD 1324–Present) (Wang, 1957, 1985; Pulleyblank, 1984, 1991; Shi, 2002; Handel, 2015; Pan and Zhang, 2015; Peyraube, 2020; Shen, 2020). All transcriptions of Middle Chinese and Mandarin in this paper are given according to Baxter and Sagart (2014), with reference to *Zhongyuan Yinyun* (Rhymes of the Central Plain; Zhou, [1324] 1996) and reconstructions of *Zhongyuan Yinyun* in Pulleyblank (1984, 1991) and Chou (1993). Tone marks are omitted since they are irrelevant to the present study.

As shown in Table 1, [i] in the syllables [fi] and [gwijH] was diphthongized to [ei] in Mandarin. However, [i] in the syllables [bi], [mi], [pi], and [p^hi] has a more complicated pattern. To exemplify, the two morphemes ‘low, humble’ (卑 [pjie]) and ‘cover, protect’ (庇 [pjij]) have similar pronunciations in Middle Chinese, but they have different pronunciations in Mandarin: the morpheme ‘low, humble’ has been diphthongized into [pei], while the morpheme ‘cover, protect’ remains [pi]. Similarly, [i] in the morpheme ‘love, flatter’ (媚 [mijH]) in Middle Chinese is realized as [ei] in Mandarin, while [i] in the morpheme ‘a kind of deer’ (麋 [mij]) remains [i] in Mandarin. Chen (1976) suggests that diphthongization of [i] in the syllables [bi], [mi], [pi], and [p^hi] is a highly irregular process in the sense that neither manner of articulation of the bilabial initials, prosodic

features, nor fine distinctions among these syllables in Middle Chinese could explain why [i] has been diphthongized into [ei] in some syllables, while has remained [i] in other syllables. In the next section, statistical analysis is used to locate factors to account for these exceptions to diphthongization of [i] to [ei], i.e., those morphemes that remain [i] in Mandarin.

4 Exceptions vs. non-exceptions

The paper firstly relies on Baxter and Sagart (2014), with reference to *Zhongyuan Yinyun* (Rhymes of the Central Plain; Zhou, [1324] 1996) and reconstructions of *Zhongyuan Yinyun* in Pulleyblank (1984, 1991) and Chou (1993), to locate morphemes of [fi], [-ui], [vi], [bi], [mi], [pi], and [p^hi] in Middle Chinese. Then the paper uses the CCL Corpus (Center for Chinese Linguistics PKU) to look for related information concerning both morphemes that have been diphthongized into [-ei] and those that remain [-i] in Mandarin. The CCL Corpus is composed of two databases: an Old Chinese and Middle Chinese database and a Modern Mandarin database. It also permits searching for data according to Chinese dynasties. Another benefit of the corpus is its capacity, over 470 million Chinese characters from a wide range of sources.

Diphthongization of [i] to [ei] began no later than the end of the 16th century and finished no later than the beginning of the 19th century (Chen, 1976; Luo, 2008; Shen, 2020). As the time phase of diphthongization was mainly within the Qing dynasty (1644–1912), data from the Qing dynasty were extracted. In addition, data from the Ming dynasty (1368–1644) were also extracted to calculate frequency change from the Ming dynasty to the Qing dynasty.

Altogether this paper locates 201 related morphemes after the exclusion of obsolete morphemes. Among them, 109 morphemes have been diphthongized to [ei] in Mandarin, and 92 morphemes remain [i] in Mandarin. The factors for statistical analysis, their respective factor levels, and statistical analysis results are reported below in Table 2.

Table 2: Data and results for the binary logistic regression model
(exceptions vs. non-exceptions)

Factor	Factor level	Estimate	Std. Error	z	<i>p</i>	
Intercept		2.46	0.34	7.17	<0.00	*
Morphosyntactic structure (1644–1912)	Free	0.27	0.43	1.21	0.63	
	Bound					
Word class (1644–1912)	Function	-1.37	0.91	1.50	0.79	
	Content					
Normalized frequency (1644–1912)	Numerical	-0.00	0.00	0.13	0.90	
Frequency dummy (1644–1912)	Low	-0.08	0.04	1.96	0.04	*
	Medium					
	High					
Frequency change from between 1368 and 1644 to between 1644 and 1912	Numerical	-0.14	0.46	0.73	0.12	
Frequency change from between 1368 and 1644 to between 1644 and 1912 dummy	Decrease	-0.17	0.38	0.46	0.65	
	Increase					

Notes: * = $p < 0.05$.

|z| stands for the absolute value of z as given in the GraphPad Prism version 8.0.0 for Windows.

4.1 Factors and factor levels in Table 2

As stated in Section 2.1.1, Donohue (2005) claims sound change advances in bound grammatical morphemes more completely than in free lexemes. Bybee (2002), Guy (1991b), Baranowski and Turton (2020), among others, claim that bound morphemes can affect /t, d/ deletion in English. Thus, the factor of *morphosyntactic structure (1644–1912)* with two levels *free* and *bound* was constructed to test whether the morphosyntactic structure has a role in the sound change. The time period *1644–1912* means that the data were extracted from the language dating to the Qing dynasty (1644–1912). *Free* and *bound* respectively mean that a related morpheme is mainly used either as a free or as a bound morpheme. “If a morpheme can stand alone in an utterance to represent a ... part of speech ..., it is free. If it must be augmented with additional language material ..., it is bound” (Packard, 2015, p. 264; see also Chao, 1968; Hsieh, 2016). To exemplify, the morpheme ‘love, flatter’ (媚) in Table 1 is a free morpheme because it can represent an adjective, while the morpheme ‘box’ (柜) is a bound morpheme since it must be used with another morpheme in a word.

The factor of *word class (1644–1912)* with two levels, namely the *content* and the *function* was configured to examine the contradictory claims concerning the role of

word classes in the sound change discussed in Crowley (1997), Blevins and Lynch (2009), and others in Section 2.1.3. Adjectives, nouns, verbs, etc., are classified as content words; adverbial conjunctions, auxiliary verbs, determiners, prepositions, quantifiers, etc are classified as function words, which is in line with the dichotomy of words in Phillips (1983, 2001, 2006). It may appear ideal to classify words into adjectives, adverbial conjunctions, determiners, nouns, prepositions, verbs, etc, however, for statistical analysis, we shall avoid too many factor levels.

As noted in Section 2.2.1, the frequency factor is claimed to be associated with exceptions to sound change by some scholars, although disagreement exists concerning whether high-frequency words or low-frequency words lead sound changes (Grimm, 1822; Bybee, 1985, 2000, 2002; Pierrehumbert, 2001; Bermúdez-Otero, 2007; Smith, 2012; Hay and Foulkes, 2016). The raw numerical data of *frequency between 1644 and 1912* were examined in the first place. The cross-tabulation analysis carried out on the GraphPad Prism version 8.0.0 for Windows (hereafter the GraphPad software) revealed that it was rejected as a statistically significant factor for diphthongization ($p = 0.63$). Thus the raw data of frequency between 1644 and 1912 were normalized on the GraphPad software and reported as *normalized frequency (1644–1912)* in Table 2.

The factor of *frequency dummy (1644–1912)* was configured following the debate in Section 2.2 concerning whether low-frequency words or high-frequency words lead sound changes. It was also partly configured in line with claims in Wedel et al. (2013) and Liu (n.d.). Wedel et al. (2013) claim that the relative frequency of minimal pair members, instead of the absolute frequencies, is a significant predictor of phoneme merger. Liu (n.d.) compares the relative frequencies of all morphemes involved in palatalization in Mandarin and finds that relative frequency is statistically significantly correlated with it. The present study does not refer to pair members and thus does not refer to the relative frequency of pair members. Instead, the present study refers to all morphemes involved in diphthongization. Therefore, it took into account the relative frequencies of all related morphemes following Liu (n.d.). The factor *frequency dummy (1644–1912)* has three factor levels: *low*, *medium*, and *high*. Each level takes one-third of the data: one-third of the data with the lowest frequencies in this column is marked as *low*; another one-third with the highest frequencies is marked as *high*; the remaining one-third between *low* and *high* is *medium*. As a result, *low* here does not refer to a frequency lower than a specific count. Instead, it means that the frequency of a certain morpheme is among the lowest frequencies of all morphemes involved in the diphthongization of [i] to [ei].

The next factor, namely the *frequency change from between 1368 and 1644 to between 1644 and 1912* (henceforth *frequency change*) was introduced due to the possibility that morphemes with either increased or decreased frequencies may have undergone diphthongization at different rates. For example, the frequency of the

morpheme ‘not’ (非 [fei]) in Table 1 is 5633 in the period from 1368 to 1644 and 14457 in the period from 1644 to 1912. Thus the frequency change for the morpheme ‘not’ (非 [fei]) is 8824, where the positive number means that comparing the first and the second period, its frequency has increased. It is possible to normalize the raw data of frequency change by adding all numbers with the absolute of the most negative. In this way, the most negative number will become zero, and all the other numbers become positive. However, the focus of the frequency change factor is partly on whether related morphemes have increased or decreased frequency. Therefore, the present study will use raw data instead of normalized data.

The factor of *frequency change from between 1368 and 1644 to between 1644 and 1912 dummy* (hereafter *frequency change dummy*) was introduced because it seems that whether frequency has decreased or increased is also a factor in sound change. The raw numerical data for the above factor *frequency change* were converted to categorical data with two levels: *decrease* and *increase*, with *decrease* as the reference level. The morpheme ‘not’ (非 [fei]) in Table 1 is exemplified again: its frequency increased 8824 times from between 1368 and 1644 to between 1644 and 1912, so it is marked as an *increase* for the factor of *frequency change dummy*.

4.2 The binary logistic regression results

The statistical relationship between the six factors in Table 2 and the dependent variable diphthongization of [i] to [ei] was assessed using multiple logistic regression in the GraphPad software. Model selection was guided by AIC (Akaike Information Criterion; Akaike, 1974; Burnham and Anderson, 2004), calculated probability (*p*-value), and VIF (Variance Inflation Factor; Rawlings et al., 1998; James et al., 2017). The dependent variable has two categories: *undiphthongized* and *diphthongized*, with *undiphthongized* as the reference level. *Undiphthongized* means that a related morpheme remains [i] in Mandarin, while *diphthongized* means that a relevant morpheme has been diphthongized to [ei]. A *p*-value smaller than 0.05 was considered statistically significant.

As shown in Table 2, the *frequency dummy (1644–1912)* is the only factor that has emerged as statistically significant (*p* = 0.04). Its negative coefficient indicates that the possibility of undergoing diphthongization decreases from the low level, medium level, to the high level (Estimate = -0.08). In other words, the higher the frequency of a morpheme is, the less likely for it to undergo diphthongization. Morphemes with the highest frequencies tend to be exceptions to diphthongization. Other factors like *morphosyntactic structure*, *word class*, and *frequency change* have been rejected as statistically significant.

5 Early application vs. late application

This section considers the morphemes that have been diphthongized to [ei] in Mandarin to explore factors that account for morphemes leading this sound change process.

5.1 Data source

This paper relies on works compiled at the beginning of diphthongization to look for morphemes that were at the forefront of this process and then carries out statistical analysis. It may seem that works compiled by Chinese scholars in the 17th century are the best choice since diphthongization began no later than the end of the 16th century (Chen, 1976; Luo, 2008; Shen, 2020). However, the choice is not as straightforward as it appears to be: dictionaries and books compiled by Chinese scholars before the 20th century use *fanqie* (反切), a traditional method of indicating the pronunciation of a Chinese character by using two other Chinese characters. For example, the pronunciation of the character 唐 might be represented as the following: 徒郎. It roughly means that the initial of 唐 is the same as that of 徒, and the final of 唐 is the same as that of 郎. This representation makes it circular and thus difficult to understand the pronunciations of characters and morphemes they represent since the Chinese writing system is a representative logographic system, not a phonographic system like English. In contrast, dictionaries compiled by missionaries to China use a Romanization system and can provide a relatively clear picture of the pronunciation of Mandarin during the time concerned.

Aid to the Eyes and Ears of Western Literati (Xiruermuzi; Trigault, [1626] 1957) is a dictionary that contains the first Romanization system of the Chinese written language, and is an essential guide to the pronunciation of Chinese characters (Wang, 2016; Li, 2020).

As noted in Section 4, this paper locates 201 morphemes related to the diphthongization of [i] to [ei]. In this section, we focus solely on the 109 morphemes that have been diphthongized to [ei] in Mandarin. The paper uses *Aid to the Eyes and Ears of Western Literati* (Trigault, [1626]1957) to locate morphemes that were at the forefront of diphthongization of [i] to [ei]. Then the paper uses the CCL corpus to look for related information concerning all the 109 morphemes and locate factors in morphemes leading the diphthongization.

5.2 Statistical analysis results: early application vs. late application

The dictionary *Aid to the Eyes and Ears of Western Literati* (Trigault, [1626] 1957) was compiled during the time of the Ming dynasty (1368–1644). Accordingly, the focus of

this research is on the data from the Ming dynasty, and frequency change is assumed to be a factor in sound change. To be able to calculate the frequency change, the data related to frequency that came before the Ming dynasty is needed. The Ming dynasty was preceded by the Yuan dynasty (1271–1368). However, the Yuan dynasty lasted for less than one hundred years and there is little data to work on. As a result, this study extracted data from both the Yuan dynasty and the Southern Song dynasty (1127–1279). To simplify it for readers who are unfamiliar with Chinese history, the paper henceforth refers to *frequency change from the Southern Song and Yuan dynasties to the Ming dynasty as frequency change from between 1127 and 1368 to between 1368 and 1644*. The data and statistical analysis results are shown in Table 3.

Table 3: Data and results for the binary logistic regression model
(early application vs. late application)

Factor	Factor level	Estimate	Std. Error	z	p	
Intercept		-0.69	0.215	4.10	0.02	*
Normalized frequency (1368–1644)	Numerical	0.01	0.01	1.37	0.21	
Frequency dummy (1368–1644)	Low	0.09	0.02	1.98	0.03	*
	Medium					
	High					
Frequency change from between 1127 and 1368 to between 1368 and 1644	Numerical	0.61	0.27	1.34	0.15	
Frequency change from between 1127 and 1368 to between 1368 and 1644 dummy	Decrease	0.52	0.28	1.89	0.04	*
	Increase					

Notes: * = $p < 0.05$.

|z| stands for the absolute value of z as given in the GraphPad software.

The raw data of frequency (1368–1644) does not show the normal distribution and were thus normalized on the GraphPad software, and reported as *normalized frequency (1368–1644)*.

The binary logistic regression analysis carried out on the GraphPad software revealed that the factors of *frequency dummy (1368–1644)* and *frequency change from between 1127 and 1368 to between 1368 and 1644 dummy* have statistically significant correlation with morphemes leading diphthongization of [i] to [ei] ($p = 0.03, 0.04$). The positive value of the coefficient of *frequency dummy (1368–1644)* suggests that this factor has an additive effect on diphthongization (Estimate = 0.09): the possibility of leading diphthongization increases from the low level, medium level, to the high level of *frequency dummy (1368–1644)*. In a similar vein, the positive value of the coefficient of *frequency change from between 1127 and 1368 to between 1368 and 1644 dummy*

indicates that a morpheme that has an increased frequency tends to undergo diphthongization first (Estimate = 0.52). To sum up, the two factors to account for morphemes leading diphthongization of [i] to [ei] are *frequency* and *frequency change*.

5.3 Frequency: exceptions vs. early application

Another statistical analysis was carried out to examine differences between the frequencies of the exceptional morphemes to diphthongization of [i] to [ei] in the time frame of 1644 to 1912 and the frequencies of the leading morphemes in the time frame of 1368 to 1644. The two sets of data were firstly normalized on the GraphPad software. A Mann-Whitney test carried out on the same software shows that statistically significant differences exist between the two sets of data ($p = 0.04$). Descriptive statistical analysis of the raw data was also carried out on the GraphPad software. The mean frequency of the exceptional morphemes is 926.8, while the mean frequency of the leading morphemes is 658.3. The highest frequency of the exceptional morphemes is 8229, while the highest frequency of the leading morphemes is 5662. Both the mean frequency and the highest frequency of the exceptional morphemes are about 1.4 times higher than those of the leading morphemes. The present study cannot draw any conclusions on whether the multiple of 1.4 may be universal or whether it changes from one sound change process to another. To do so, more sound change processes within one language as well as sound processes across languages need to undergo the analyses. The topic proves to be a boon for later research.

6 Conclusion

Word class and morphosyntactic structure, or morphological condition in a broader term, have been rejected as statistically significant both in accounting for exceptions to diphthongization and leading morphemes in diphthongization. This suggests that morphological condition does not have a role in diphthongization.

Previous studies mainly focus on whether high-frequency morphemes or low-frequency morphemes lead sound change. The present study reveals that the role of the frequency factor in sound change is more complex than the debate in previous studies. The frequency factor has been proven as statistically significant both for exceptions to diphthongization of [i] to [ei] and leading morphemes in it. What proved interesting is the following two points: (1) high-frequency morphemes tend to be exceptions to diphthongization; (2) among morphemes that underwent diphthongization, high-frequency morphemes tend to lead diphthongization. More plainly, morphemes with the highest frequency tend to be exceptions to diphthongization. High-frequency morphemes among non-exceptional morphemes

tend to lead diphthongization, although the frequencies of these high-frequency morphemes tend to be less than the frequencies of exceptional morphemes.

Another statistically significant factor to explain leading morphemes in diphthongization is frequency change: a morpheme that has an increased frequency tends to undergo diphthongization earlier. This factor has not emerged as statistically significant to account for exceptions to diphthongization. Put differently, frequency change is not correlated with exceptions to diphthongization but correlated with early application of diphthongization. This factor has generally been overlooked in previous studies.

It can be debated that the conclusions in this paper are based on one language sample and cannot be applied to all languages. To answer this question, research into a parallel process in another language is clearly called for. Such an analysis constitutes an exciting area for future research.

Acknowledgments

For help in getting this article to its final form, I am grateful to Prof. Eiji Yamada, Prof. Greg Bevan, and Prof. Kuixin Zhao for advice and discussion, to Prof. Changyun Moon and Prof. Robert Long for editing my paper, and to the anonymous reviewer and the editors of the present journal for detailed and helpful feedback. All remaining errors are my own responsibility. This work was funded by JSPS Grant-in-Aid for Early-Career Scientists (KAKENHI-PROJECT-20K13072).

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