Vowel Quality Cues to Variable Nasal Adaptation in Mandarin Loanword Phonology

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1 Introduction

Variable adaptation in loanword phonology has not always been analyzed in detail, but some studies on Standard Mandarin (SM) loanword phonology, where a seemingly wide range of variation is present, have started to uncover cases where instances of variable adaptation are contextually conditioned (e.g. Hsieh, Kenstowicz, & Mou, 2009 on SM nasal codas; Y.-H. Lin, 2008a, 2008b on SM vowels). This study presents corpus and experimental data in which intervocalic English nasals are variably adapted with geminates, e.g. *Benedict* → [pan.ni:ti:k^{h}ɤ:.], or singletons, e.g. *Lina* → [li:na:] in SM. Some cases also show that one word can be adapted with and without nasal gemination, e.g. *Tiffany* → [ti:.fu:.ni:]~[ti:.fan.nei]. Taking data from a dictionary corpus, we identify two conditions in the English source words that typically trigger nasal gemination in SM loanwords: (i) *vowel type condition*: the prenasal vowel being lax and non-high and (ii) *stress location condition*: the prenasal vowel bearing the primary stress. When the prenasal vowel is an unstressed schwa or a reduced vowel in English, the adapted words can appear with or without nasal gemination. We argue that the perceived duration and nasalization of the English prenasal vowels condition which variant is preferred in SM, and we suggest how these vowel quality cues are processed and mapped onto SM phonological representation by monolingual and bilingual SM speakers.

We present the corpus data and observed adaptation patterns in section 2. A perceptual similarity experiment and the results are presented in section 3. General discussion is given in section 4. We draw a conclusion in section 5. The list of test items and samples of filler items for the experiment are presented in section 6.

2 The corpus data and generalizations (Huang & Lin, 2016)

The current corpus data are collected from Appendix I, a list of common British and American names, of A New English-Chinese Dictionary (1988). The corpus consists of around 2400 British and American male and female names; more than 1600 nasal consonants in different syllable positions are examined. We also found some words outside the dictionary with a prenasal low back [ɑ] that are not adapted with nasal gemination even though they fulfill both the vowel type and stress location conditions for nasal gemination.

By looking only at intervocalic nasal consonants in English, the data from the corpus can be grouped into three types: adaptation in SM loanwords with nasal gemination, those without gemination, and those that are variably adapted with or without nasal gemination. Each type consistently occurs under specific conditions. The two main factors that condition the adaptation of nasal gemination in SM loanwords are the prenasal vowel quality and the location of stress. The prenasal vowel in English has to be lax and non-high and bears the primary stress. The examples in the three subcategories in (1) illustrate how intervocalic nasal singletons in English are faithfully adapted in SM loanwords; examples in (2) show how intervocalic nasal singletons in English are adapted with nasal gemination; examples in (3) present cases when free variation occurs.

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(1) No nasal gemination:

a. When the prenasal vowel is long or a diphthong.

ENG [ˈV:N]	MAN [V:.N]
ˈLi<u>n</u>a	[li:.<u>n</u>a:] (long or tense vowel)
ˈDow<u>n</u>ey	[tau.<u>n</u>i:] (diphthong)
ˈBru<u>n</u>o	[pu:.lu:.<u>n</u>uo]
ˈMo<u>n</u>a	[m^{w}o:.<u>n</u>a:]
ˈSo<u>n</u>y	[s^{w}o:.<u>n</u>i:]

b. When the postnasal vowel bears the primary stress.

ENG [VˈNV]	MAN [V:.NV]
Deˈnise	[ti:.ni:.sɻ:]
Beˈnet	[pei.nei.t^{h}ɤ:]
Boˈnita	[p^{w}o:.ni:.ta:]
Reˈnei	[lei.<u>n</u>i:]

c. When the prenasal vowel is [ɑ].

ENG [ˈCɑNV]	MAN [a:.NV]
Caˈba<u>n</u>a	[k^{h}a:.pa:.<u>n</u>a:]
Asˈta<u>n</u>a	[a:.sɻ:.t^{h}a:.<u>n</u>a:]
Guiˈa<u>n</u>a	[tɕi:.ja:.<u>n</u>a:]
Miˈa<u>m</u>i	[maɪ.a:.<u>m</u>i:]

(2) With nasal gemination: When the prenasal vowel is nonhigh, lax, and bears the primary stress.

ENG [ˈVnV]	MAN [Vn.nV]
Diˈa<u>n</u>a	[tai.a<u>n</u>.<u>n</u>a:]
ˈFe<u>n</u>ick	[fe<u>n</u>.<u>n</u>i:.k^{h}ɤ:]
ˈDa<u>n</u>ica	[ta<u>n</u>.<u>n</u>i:.ka:]
ˈE<u>n</u>id	[ə<u>n</u>.<u>n</u>i:.tɤ:]
Heˈle<u>n</u>a	[xɤ:.la<u>n</u>.<u>n</u>a:]
ˈLeo<u>n</u>ard	[lu<u>n</u>.<u>n</u>a:.tɤ:]

Figure 1 shows that nasal gemination in Mandarin loanwords is cued by English prenasal stressed nonhigh lax vowels. Nasal gemination rarely happens when the prenasal vowel is high, tense, or unstressed.

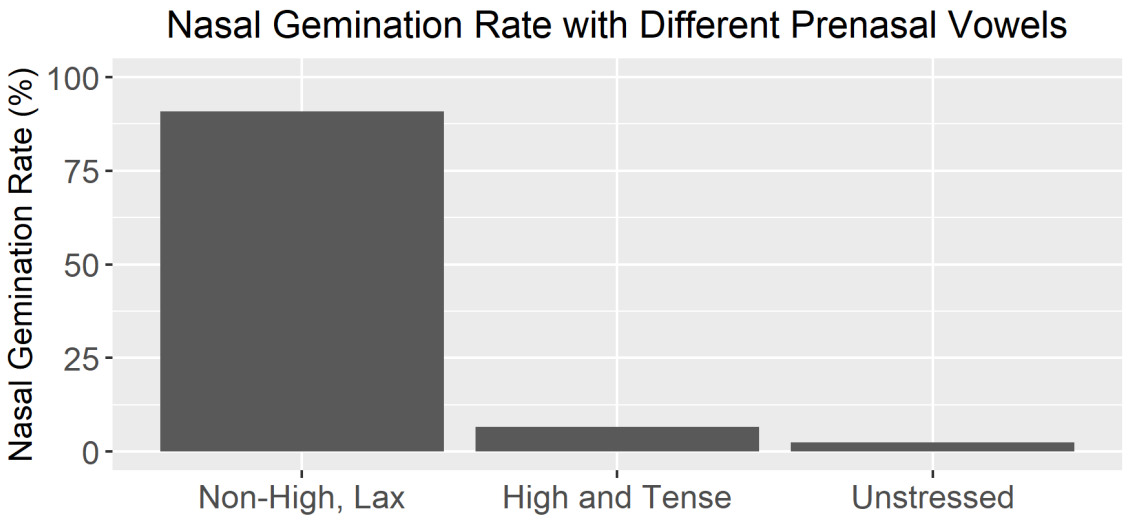

Figure 1. Percentage of nasal gemination with different prenasal vowel conditions.

Table 1 shows the actual number of the appearance of nasal gemination with different English prenasal vowels.

	Non-High, Lax				High and Tense		Unstressed
Vowels	æ	ɔ	ɛ	ʌ	ɪ	Tense vowels	Unstressed vowels
Number	42	30	29	8	4	4	3
Percentage	35.29%	25.21%	24.36%	6.72%	2.52%	3.33%	2.52%
Subtotal	90.8% (109/120)				6.67% (8/120)		2.5% (3/120)
Total=120 (100%)							

Table 1. Nasal gemination in SM loanwords with different English vocalic contexts and stress condition.

From Figure 1 and Table 1, we can see that English vowel quality, such as tenseness and height, and stress are the two main factors that affect whether nasal gemination appears in SM loanwords or not. If we looked more closely, among the four non-high lax vowels, [æ, ɔ, ɛ, ʌ], the lower the vowel is, the more nasal gemination is present in SM loanwords. English high vowels and tense vowels rarely trigger nasal gemination in SM loanwords.

Examples in (3) show free variation cases. The variation adaptation forms are verified by Google search, i.e. two types of transliterations are searched on Google[1]. The English prenasal vowels are either a [ə] or a reduced vowel [ɪ]. In addition, the prenasal vowel is stressless; it bears neither the primary word stress nor the secondary stress.

(3) Free variation: When the prenasal vowel is a [ə]

ENG [ənV]	MAN [Vn.nV] / [VnV]
Tiffa<u>n</u>y	[ti:.fa<u>n</u>.<u>n</u>ei] ~ [ti:.fu:.<u>n</u>i:]
Lympa<u>n</u>y	[lin.pə<u>n</u>.<u>n</u>i:] ~ [lin.pa:.<u>n</u>i:]
Mela<u>n</u>ie	[mei.la<u>n</u>.<u>n</u>i:] ~ [mei.la:.<u>n</u>i:]
Alba<u>n</u>y	[au.pə<u>n</u>.<u>n</u>i:] ~ [au.p^{w}o:.<u>n</u>i:]
Stepha<u>n</u>ie	[ʂɻ:.ti:.fə<u>n</u>.<u>n</u>i:] ~ [ʂɻ:.ti:.fu:.<u>n</u>i:]

To sum up, the English intervocalic nasal adaptation is not a simple one-to-one segment mapping process. The English intervocalic nasal can be adapted with nasal gemination, without nasal gemination, and can sometimes vary between the two. The adaptation process is conditioned by the English prenasal vowel quality and the stress location in the word. To trigger nasal gemination in SM loanwords, the English prenasal vowel has to be lax and bear the primary stress. In other words, if the prenasal vowel is tense, a diphthong, or is phonetically long, nasal gemination does not occur. As for stress location, if the post-nasal vowel bears the primary word stress, which also means the English syllabification is clear, e.g. *Boˈnita*, then the nasal is clearly syllabified to the onset of the second syllable. Nasal gemination barely occurs in SM loanwords. For the source words that are adapted with two forms in SM loanwords, vowel quality and stress seem also play an important role during the adaptation process since the English prenasal vowel has to be either a [ə] or a reduced vowel [ɪ] and it also has to be stressless.

3 Perceptual experiment

A perceptual similarity task was conducted for both Mandarin monolingual and Mandarin-English bilingual speakers. Our goals are to answer the following questions:

i. Do the prenasal vowel quality and stress location trigger nasal gemination in Mandarin loanwords?
ii. Which variant is preferred under what contexts?
iii. Does bilingualism play a role?

[1] The dictionary only gives one correspondence for each word.

3.1 *Hypothesis* Based on the generalizations identified in the corpus data, we hypothesize that nasal gemination is induced by English prenasal vowel quality and stress location, i.e. the English prenasal vowel should be non-high and lax and bears the primary stress.

3.2 *Participants* The experiment was run on two groups with different language backgrounds. In the following, we present the group size and participants' language background.

Mandarin monolingual group Thirty three adult Mandarin monolingual undergraduate students volunteered to participate in the experiment. Their age fell in between 18 and 21 years old. They studied at National Chengchi University majoring in different subjects. None were English or linguistics majors. They were native Mandarin speakers born in Taiwan with normal hearing. At the time of the experiment, they had no study abroad and living experience in any English speaking country, and they do not speak or use Chinese dialect in their daily life. Their English proficiency was assessed by self-report before the experiment and by a native American English speaker after the experiment.

Mandarin-English bilingual group Twenty four adult Mandarin-English bilingual undergraduate and graduate students majoring in different subjects volunteered to participate in the experiment. Their ages fell in between 21 and 33 years old. At the time of the experiment, they either studied or taught at Michigan State University or had a job in a company. They were native Mandarin speakers born in Mainland China with normal hearing. They do not speak and do not use any Chinese dialect at home. At the time of the experiment, they had lived and studied or worked in the U.S. for more than 3 years. They had to use English as their dominant language for the classes they were taking or teaching, and at work. Their English proficiency was assessed using a self-report TOFEL score. Their TOFEL scores were all higher than 100 (the global average score is 78).

3.3 *Materials* The experiment has 42 test items and 85 filler items (see Appendix). The English inputs were read out loud carefully by one female native American English speaker, with linguistics training from Michigan. The possible Mandarin loanword outputs were produced by one female native Mandarin speaker from Taiwan who does not speak any Chinese dialect and who has linguistics training. The stimuli were tokens in a three-word series. Each sound string consists of two possible adapted loanword forms in Mandarin and a pseudo word. The order of the words is {Mandarin, Mandarin, Pseudo word input}.

The corpus data show that nasal gemination strongly correlates to the prenasal vowel quality in English. Therefore, all the English tense and lax vowels that occupy the prenasal vowel position were tested, e.g. ENG [ˈbe̲ini]/ENG [ˈbɛ̲ni]. The corpus data show that stress location affects the appearance of nasal gemination as well. Hence, pseudo words with the primary stress falls on the prenasal and postnasal vowel were tested, e.g. ENG [ˈbɛni]/ENG [bɛˈnita].

Test items for variable adaptations were all with a prenasal vowel [ə] in trisyllabic words and with the primary stress on the initial syllable, e.g. ENG [ˈfɪbə̲ni]. Another set of test items contrasting the prenasal vowel [æ] and the low back [ɑ] in trisyllabic and disyllabic words, e.g. ENG [bəˈbæ̲nə]/ENG [bəˈbɑ̲nə], ENG [ˈbæ̲nə]/ENG [ˈbɑ̲nə], were tested as well.

As for the tone pattern of the two possible Mandarin outputs, the tone patterns of the consecutive characters in the possible adapted Mandarin outputs were the same if there were no systematic gap, e.g. MAN [pēi.ní:], MAN [pān.ní:], ENG [ˈbɛ̲ni].

In the current experiment, we only used the alveolar nasal [n] to be the target because when compared to [m] and [ŋ], the intervocalic English [n] is adapted with nasal gemination most frequently with 83.19%. The geminated nasal is either identical to the source form or transformed to [ŋ] to agree on backness with its preceding vowel (cf. Hsieh et al., 2009). Filler items are monosyllabic and disyllabic words that are with and without nasals.

3.4 *Procedures* A force choice perceptual similarity ABX task was conducted. The experiment is different from traditional ABX tasks because neither A nor B was identical to the pseudo input word X. The two possible Mandarin outputs A and B were created for adaptation of X, e.g. MAN[pan.ni], MAN[pei.ni], ENG[ˈbɛni]. After the participants listened to a sound string of ABX and BAX, they decided which one of A and B was more perceptually similar to X and they further chose between them. The same

experiment was run on monolingual Mandarin and Mandarin-English bilingual speakers.

3.5 *Results* In this subsection, we present and compare the perceptual similarity force choice task results from the Mandarin monolingual and Mandarin-English bilingual speakers. The results are presented separately according to different conditions—vowel type condition, stress location condition, free variation adaptation, and [ɑN] adaptation. T-test and, or ANOVA were run to analyze the results.

Vowel type condition We compared the nasal gemination preference of bilingual and monolingual speakers (see Figure 2). T-tests of the vowel type condition reveal that the preference for nasal gemination is significantly higher in both monolingual [$t(32)=7.782$, $p<0.001$] and bilingual [$t(23)=7.582$, $p<0.001$] groups when the prenasal vowel is lax in English, although the percentage of lax vowel triggering nasal gemination in the corpus data is a lot higher (cf. Figure 1, Table 1), we still claim that English prenasal vowel quality decides the presence of nasal gemination in Mandarin loanwords. The two-way ANOVA analysis shows that there is no significant interaction effect on nasal gemination rate ($F(1,55)=0.044$, $p=0.129$) between bilingualism and the prenasal vowel type. For the main effect, there is no significant difference between bilingual and monolingual speakers on nasal gemination rate ($F(1,55)=0.003$, $p=0.711$). However, there is a significant effect for vowel tenseness on nasal gemination rate ($F(1,55)=2.820$, $p<0.001$).

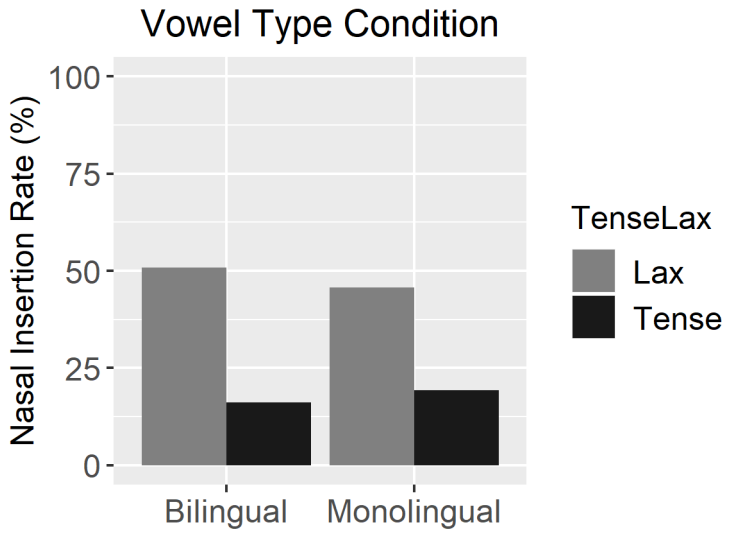

Figure 2. Nasal gemination rate with different prenasal vowel quality and stressed prenasal vowels: $CV\acute{}_{tense}NV$ vs. $CV\acute{}_{lax}NV$

Stress location condition Figures 3 and 4 show how monolingual and bilingual speakers adapt the intervocalic [n] when English word stress falls on prenasal and postnasal vowels. We already knew that English prenasal tense vowels do not trigger nasal gemination in Mandarin as frequently as lax vowels (see Figure 2), and that based on the corpus data, when the stress falls on the post nasal vowel with a clear syllabification, nasal gemination rarely shows up in Mandarin loanwords. Therefore, we only selected test items with $'CV_{lax}NV$ structure and compared them with all test items with CV'Nita structure (Figure 3). We also compared the nasal gemination rates of CV_{tense}Níta and CV_{lax}Níta syllable structures (see Figure 4).

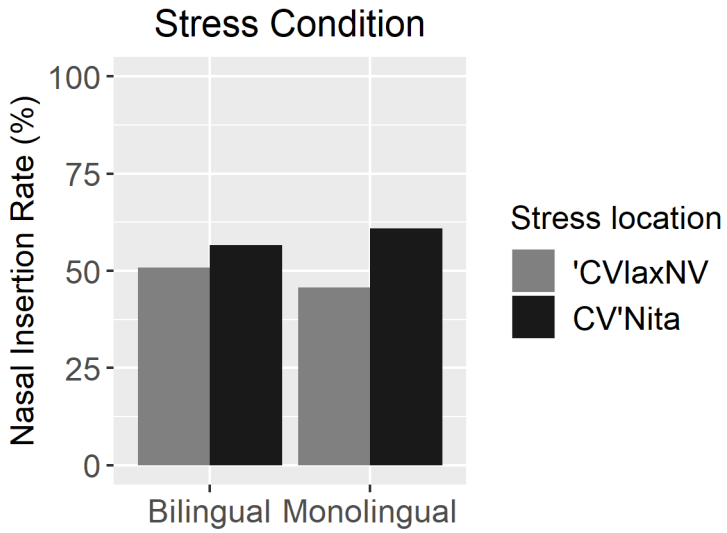

Figure 3. Nasal gemination rate with stressed lax prenasal vs. stressed postnasal vowels: CV́ $_{lax}$NV vs. CVNíta

In Figure 3, the two-way ANOVA analysis shows that there is no significant stress location effect when the stress falls on either the prenasal vowel or the postnasal vowel ($F(1,55)=2.787$, $p=0.101$). There is no significant difference between speaker groups when the stress is on different syllables ($F(1,55)=0.030$, $p=0.863$).

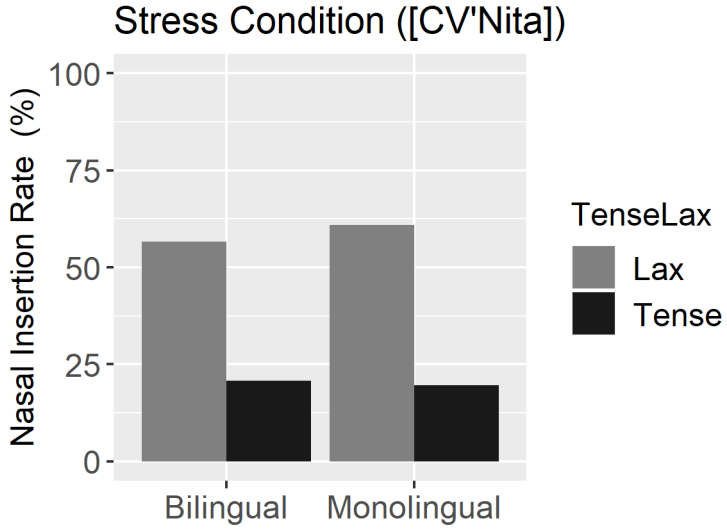

Figure 4. Nasal gemination rate with prenasal lax vs. tense vowels and stressed postnasal vowels: CV$_{tense}$Níta vs. CV$_{lax}$Níta

Figure 4 shows that preference for nasal gemination is significantly higher when the prenasal vowel is lax in both groups ($F(1,55)=4.124$, $p<0.001$) and there is no significant interaction between bilingualism and the tenseness of English prenasal vowel ($F(1,55)=0.020$, $p=0.266$). Bilingual and monolingual groups do not show significant difference ($F(1,55)=0.006$, $p=0.563$) on nasal gemination. In other words, nasal gemination preferred in both groups when the prenasal vowel is lax in English.

Free variation According to the corpus data, words with [ˈCVCəNV] tend to have variable adaptation forms in Mandarin. Figure 5 shows how bilingual and monolingual speakers adapt the intervocalic nasal with [ə] as the prenasal vowel. The results show that the monolingual speakers prefer the outputs with nasal

gemination significantly more than the bilingual speakers in the perceptual similarity task (t(35.445)=2.622, p=0.013). We can interpret that bilingual speakers tend to have variable adaptation. In all the responses from the bilingual speakers, 60.2% of the time, they chose nasal gemination as the perceptual similar output; whereas, monolingual speakers' nasal gemination rate is up to 74.7%.

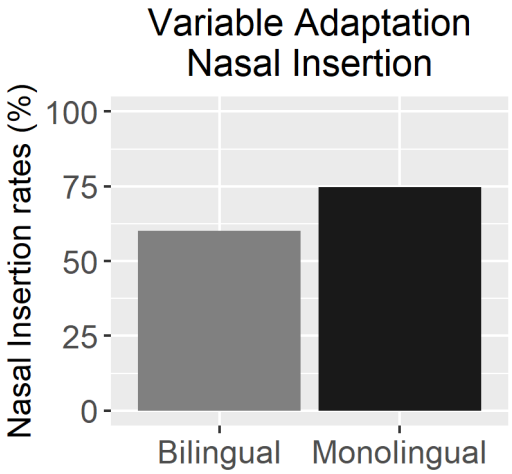

Figure 5. Nasal gemination rate when the prenasal vowel is [ə]: CV́CəNV.

[aN] Figure 6 shows that both bilingual (14.7%) and monolingual (8%) groups do not prefer nasal gemination in Mandarin outputs when the English prenasal vowel is low back [ɑ]. The two-way ANOVA analysis reveals that there is no significant interaction between bilingualism and the quality of the English prenasal vowel (F(1, 55)=0.996, p=0.322). The analysis shows that nasal gemination is significantly not preferred in both monolingual and bilingual groups when the English prenasal vowel is low back [ɑ] (F(1, 55)=118.396, p<0.001). There is no significant difference between monolingual and bilingual speakers (F(1, 55)=0.192, p=0.662). The experimental results tell us that low back [ɑ] behaves significantly differently from other lax vowels in English during the intervocalic nasal adaptation process.

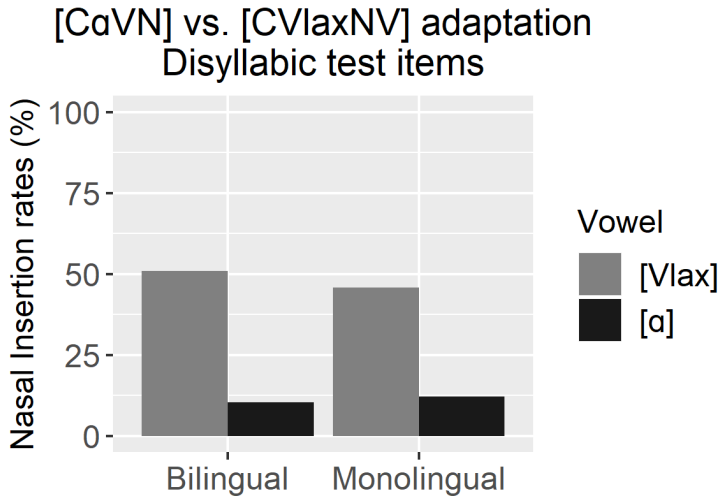

Figure 6. Comparison of nasal gemination rate when the English prenasal vowel is low back [ɑ] and all the other English lax vowels.

Figure 7 shows that similar to the corpus pattern, the low back vowel [ɑ], like other tense vowels, does not trigger nasal gemination in Mandarin loanwords. The two-way ANOVA analysis reveals that there is no significant interaction between groups with different language background and the prenasal vowel

quality (F(1, 55)= 0.037, p=0.847). The preference for nasal gemination of monolingual and bilingual speakers was similar (F(1, 55)=0.349, p=0.557). Both groups do not prefer inserting an extra nasal when the prenasal vowel is [ɑ] and other tense vowels in English. There is no significant difference on nasal gemination between [ɑ] and other English tense vowels (F(1, 55)=3.079, p=0.08).

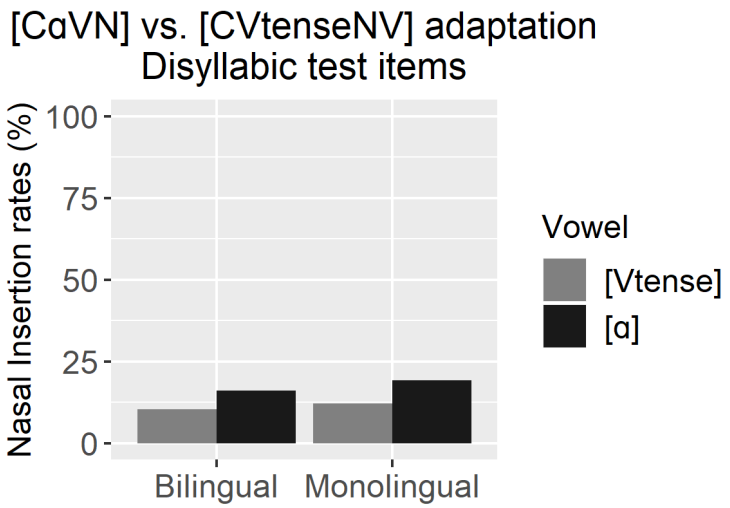

Figure 7. Comparison of nasal gemination rate when the English prenasal vowel is low back [ɑ] and all the other English tense vowels.

4 General discussion

After analyzing the results from all participants with different language backgrounds, in what follows, we discuss: i) the similarities and differences between the experimental results and the corpus data and, ii) the causes of the differences, and iii) the comparison between monolingual and bilingual groups.

The results indicate that English prenasal vowel duration and nasalization contribute to the selection of the geminate variant in SM. In general, the experimental results from the monolingual and the bilingual groups are consistent with the analysis of the corpus data. The corpus data analysis shows that nasal gemination accounts for 90.8% of English intervocalic nasal adaptation when the prenasal vowel is non-high and lax. The experimental results also show that English prenasal vowel quality plays an important role in nasal gemination in Mandarin loanword adaptation although the gemination rate is not as high as in the corpus (50%-63%). The experimental results differ from the corpus data in respect of stress location condition. However, all these differences are interpretable.

Given the bimoraic requirement for full-toned SM syllables (Duanmu, 2007), English prenasal lax vowels are perceived as monomoraic vowels in SM and hence are more likely to trigger nasal gemination to produce a bimoraic [CVN] syllable. In contrast, tense vowels tend to have a direct faithful match and form a heavy [CV:] syllable in SM. We claim that Mandarin speakers take the English prenasal vowel duration as one of the major cues for intervocalic nasal adaptation. The fact that even higher gemination rate occurs as a result of a very short prenasal [ə] further supports the vowel duration effect.

The difference on the nasal gemination rate between the corpus and the experimental data can be attributed to how the participants adapt the prenasal vowels (Lin, 2008b, 2011, 2012). Take the prenasal vowel [æ] as an example, it can be adapted as [a_c], [je], [a], [ai], and [ja][2]. In the current experimental setting, the two given SM outputs of [æ] were [a_c] without nasal gemination in an open syllable and [a] with nasal gemination in a closed syllable. If the participant had adapted English [æ] as [a], the form with nasal gemination would be selected as the perceptually similar form to the English input.

Stronger vowel nasalization in non-high vowels triggers higher gemination rates in SM (Figure 8 & Table 2 below). As we can see in Figure 8, the lower the vowel, the higher rate of nasal gemination is. In

[2] The variation could be due to speakers' perception or the phonotactic constraints of SM.

Table 2, we also see the dichotomy between high vowels and non-high vowels in terms of the vowel nasalization ratio with respect to the total vowel duration.

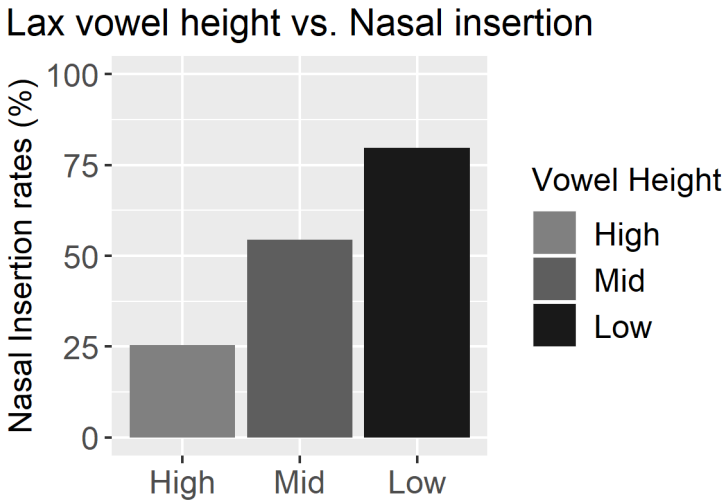

Figure 8. Nasal gemination rate in relation to the prenasal lax vowel height regardless of stress location.

Prenasal V_{lax}	V duration (ms)	Nasalization within the V (ms)	Ṽ/V
[ɪ]	86	60	69%
[ʊ]	107	63	58%
[ɛ]	115	92	80%
[ɔ]	144	111	77%
[æ]	157	122	78%

Table 2. The actual prenasal vowel duration and vowel nasalization and the percentage.

Adding a nasal to a short or lax vowel not only makes a better phonetic match on vowel duration and nasalization, but also fulfills SM phonotactic constraints (cf. Yip, 1993 on gemination in Cantonese). Overall, the vowel duration cue appears to be the dominant force, as indicated by the higher geminate rate after a prenasal schwa than other lax vowels (see Table 3). The average duration of prenasal [ə] with CV́CəNV structure is 33.5ms. All the other average vowel duration can be found in Table 2 above.

	Prenasal [ə]	Prenasal V_{lax}
Monolingual Gemination %	74.7	45.8
Bilingual Gemination %	60.2	50.8

Table 3. Nasal gemination rates between prenasal [ə] and prenasal lax vowels of participants with different language background.

The patterns observed in the experimental results of stress condition are not identical to the patterns observed in the corpus data. We first compared ˈCV_{lax}NV and CVˈNita (Figure 3). The experimental results do not pattern with the generalization observed in the corpus data. Presumably, CVˈNita test items should have very little response with nasal gemination because according to Hayes (2009) the intervocalic nasal is clearly syllabified as an onset. However, the results show that ˈCV_{lax}NV and CVˈNita have a similar adaptation pattern, i.e. both structures show that nasal gemination is preferred. Figure 4 presents the comparison between CV_{lax}ˈNita and CV_{tense}ˈNita. For the CV_{lax}ˈNita test items, both monolingual and bilingual groups chose the outputs with nasal gemination as the perceptually more similar one. We suggest that this can be attributed to the fact that the English input recordings show clear nasalization of unstressed prenasal lax vowels. Hence, Mandarin speakers from both groups perceive the short duration of the vowel with heavy nasalization and add another nasal consonant to fulfill the Mandarin $\mu\mu$-syllable constrain, and

the fine acoustic nasal cue on the prenasal vowel. Table 4 below shows the total vowel duration of the prenasal vowel, the duration of the proportion of the nasalized part within the prenasal vowel, and the percentage of vowel nasalization of the CV_{lax}ˈnita test items. Vowel nasalization indicates that both groups of speakers rely on perception cues to match vowel duration and nasality through nasal gemination.

	V duration (ms)	Nasalization within the vowel (ms)	Ṽ/V
[bɪˈnita]	52	39	75%
[bʊˈnita]	83	66	79.5%
[bɛˈnita]	67	57	85.1%
[bɔˈnita]	123	108	87.8%
[bæˈnita]	120	105	87.5%

Table 4. The total prenasal vowel duration, the duration of the nasalized part in the prenasal vowel, and the proportion in percentage of vowel nasalization of the test item with CVˈnita structure.

For the prenasal low back [ɑ] cases, same as the corpus data, nasal gemination is not preferred when the English prenasal vowel is low back [ɑ]. Nasal gemination should occur if we were to treat the low back [ɑ] as a lax vowel since it would fulfill both the vowel type condition and stress location condition. The rime [ɑŋ][3] is also a possible syllable in Mandarin. However, [ɑ] almost never triggers nasal gemination in Mandarin. We proposed that [ɑ] is phonetically long in duration. Hence, it fills the X slot in C(G)VX. There is no need to geminate the nasal consonant. In addition, [ɑ] is one of the peripheral vowels in both English and Mandarin. Without sound modification, it can be faithfully mapped from English to Mandarin. Therefore, the extra repair, i.e. nasal gemination, is not necessary. Another possibility is that [ɑ] acts as a tense vowel in open syllables. Green (2001) argues that [ɑ] in English can be lax and tense in different environments. He points out that all words which [ɑ] appears in contexts otherwise restricted to tense vowels are either loanwords like *spa* and *mirage* or hypocoristics like *ma* and *pa*. Words in the current corpus data like *Cabana, Adana, Astana*, are foreign country names or exotic objects in English.

In the experiment, the lack of the stress effects as exhibited in the corpus data and the relative lower gemination rate in the prenasal stressed lax vowel context (50%~63%; cf. 90.8% in corpus) can also be attributed to the auditory experimental setting, which likely leads to auditory variation (cf. Davidson, 2007, Smith, 2006) and less access to phonological representation such as metrical structure. The monolinguals' higher gemination rate in matching English CV́CəNV likely indicates their heavy reliance on perceptual cues, whereas the bilinguals may have a better access to phonological representation to reduce the perceptual vowel duration effect to some extent, hence exhibiting lower gemination rate than monolinguals in matching English CV́CəNV (cf. Figure 5).

5 Conclusion

To conclude, variable adaptations of English intervocalic nasals are contextually conditioned. Whether nasal gemination appears in Mandarin loanwords or not depends on the prenasal vowel quality in English. In general, the experimental results pattern with the generalizations identified in the corpus. Mandarin speakers are cued by the duration and nasalization of English prenasal vowels when they adapt intervocalic nasals in English. However, under the experimental setting, they are not sensitive to the stress patterns in English.

This study contributes to a better understanding of which phonetic cues modulate variation in adapted forms and how they do so. It also showcases multiple sources for variable loanword adaptation: linguistic contexts, auditory vs. non-auditory inputs, and monolingual vs. bilingual differences.

[3] The inserted nasal is not [n] here because the place of articulation of the nasal is decided by the backness of the English prenasal vowel.

6 Appendix

I. The word list of the test items (The outputs are shown in *Pinyin*, Chinese romanization, with tone number).

Nasal insertion	Tense/lax	Stressed V	Token	possible outputs	
[ˈCVnVC]	Tense	i	[ˈbini]	bi1 ni2	bing1 ni2
		e	[ˈbeni]	bei1 ni2	ban1 ni2
		u	[ˈbuni]	bu4 ni2	ben1 ni2
		o	[ˈboni]	bo1 ni2	bang1 ni2
	Lax	ɪ	[ˈbɪni]	bi1 ni2	bing1 ni2
		ɛ	[ˈbɛni]	bei1 ni2	ban1 ni2
		æ	[ˈbæni]	bai4 ni2	ban4 ni2
		ʊ	[ˈbʊni]	bu4 ni2	ben1 ni2
		ɔ	[ˈbɔni]	bo1 ni2	bang1 ni2
		ɑ	[ˈbɑni]	ba1 ni2	bang1 ni2
[CVˈnVC]	Tense	i	[biˈnita]	bi3 ni2 ta3	bin3 ni2 ta3
		e	[beˈnita]	bei3 ni2 ta3	ben3 ni2 ta3
		u	[buˈnita]	bu3 ni2 ta3	ben3 ni2 ta3
		o	[boˈnita]	bo1 ni2 ta3	bang1 ni2 ta3
	Lax	ɪ	[bɪˈnita]	bi3 ni2 ta3	bin3 ni2 ta3
		ɛ	[bɛˈnita]	bei3 ni2 ta3	ben3 ni2 ta3
		æ	[bæˈnita]	bai4 ni2 ta3	ban1 ni2 ta3
		ʊ	[bʊˈnita]	bu3 ni2 ta3	ben3 ni2 ta3
		ɔ	[bɔˈnita]	bo1 ni2 ta3	bang1 ni2 ta3
		ɑ	[bɑˈnita]	ba1 ni2 ta3	bang1 ni2 ta3
Variable adaptation [ˈCVCənV]	Tense	i	[ˈfibəni]	fei1 ben3 ni2	fei1 bo2 ni2
		e	[ˈfebəni]	fei4 ben3 ni2	fei4 bo2 ni2
		u	[ˈfubəni]	fu1 ben3 ni2	fu1 bo2 ni2
		o	[ˈfobəni]	fo2 ben3 ni2	fo2 bo2 ni2
	Lax	ɪ	[ˈfɪbəni]	fei4 ben 3ni2	fei4 bo2 ni2
		ɛ	[ˈfɛbəni]	fei1 ben3 ni2	fei1 bo2 ni2
		æ	[ˈfæbəni]	fa3 ben3 ni2	fa3 bo2 ni2
		ʊ	[ˈfʊbəni]	fu4 ben3 ni2	fu4 bo2 ni2
		ɔ	[ˈfɔbəni]	fo2 ben3 ni2	fo2 bo2 ni2
		ɑ	[ˈfɑbəni]	fa1 ben3 ni2	fa1 bo2 ni2
[ɑ] exception [CVˈbɑnə]	Lax	ɪ	[bɪˈbɑnə]	bi3 ba1 na4	bi3 ban1 na4
		ɛ	[bɛˈbɑnə]	bei3 ba1 na4	bei3 ban1 na4
		æ	[bæˈbɑnə]	bai3 ba1 na4	bai3 ban1 na4
		ʊ	[bʊˈbɑnə]	bu3 ba1 na4	bu3 ban1 na4
		ɔ	[bɔˈbɑnə]	bo3 ba1 na4	bo3 ban1 na4
		ɑ	[bɑˈbɑnə]	ba3 ba1 na4	ba3 ban1 na4
	Lax	ɪ	[bɪˈbænə]	bi3 ban1 na4	bi3 ba1 na4
		ɛ	[bɛˈbænə]	bei3 ban1 na4	bei3 ba1 na4
		æ	[bæˈbænə]	bai3 ban1 na4	bai3 ba1 na4
		ʊ	[bʊˈbænə]	bu3 ban1 na4	bu3 ba1 na4
		ɔ	[bɔˈbænə]	bo3 ban1 na4	bo3 ba1 na4
		ɑ	[bɑˈbænə]	ba3 ban1 na4	ba3 ba1 na4

II. The word list of the filler item examples (The outputs are shown in *Pinyin*, Chinese romanization, with tone number).

	Tense/lax	Stressed V	Token	Possible output

CV(C)	Tense	i	[pi]	pi4
		e	[pe]	pei4
		u	[pu]	pu4
		o	[po]	po4
	Lax	ɪ	[pɪd]	pi4 de2
		ɛ	[pɛd]	pei4 de2
		æ	[pæd]	pai4 de2
		ʊ	[pʊd]	pu4 de2
		ɔ	[pɔd]	po4 de2
		ɑ	[pɑd]	pa4 de2
CVCV	Tense	i	[bɪˈtid]	bi3 ti4 de2
		e	[bɪˈted]	bi3 tai4 de2
		u	[bɪˈtud]	bi3 tu4 de2
		o	[bɪˈtod]	bi3 tou4 de2
	Lax	ɪ	[bɪˈtɪd]	bi3 ti4 de2
		ɛ	[bɪˈtɛd]	bi3 tai4 de2
		æ	[bɪˈtæd]	bi3 tai4 de2
		ʊ	[bɪˈtʊd]	bi3 tu4 de2
		ɔ	[bɪˈtɔd]	bi3 tou4 de2
		ɑ	[bɪˈtɑd]	bi3 ta4 de2

7 References

Davidson, L. (2007). The relationship between the perception of non-native phonotactics and loanword adaptation. *Phonology*, *24*(02), 1–36. http://doi.org/10.1017/S0952675707001200

Duanmu, S. (2007). *The phonology of standard Chinese* (2nd ed.). Oxford, UK: Oxford University Press. http://doi.org/10.1353/lan.2003.0139

Green, A. D. (2001). The tense-lax distinction in English vowels and the role of parochial and analogical constraints. *Linguistics in Potsdam*, *16*(15), 32–57.

Hayes, B. (2009). Syllabification in English. In *Introductory Phonology*. http://doi.org/https://linguistics.ucla.edu/people/hayes/251English/Readings/HayesAmbisyllabicity.pdf

Hsieh, F.-F., Kenstowicz, M. J., & Mou, X. (2009). Mandarin adaptations of coda nasals in English loanwords. In A. Calabrese & W. Leo Wetzels (Eds.), *Loan Phonology* (pp. 139–162). Amsterdam/Philadelphia: John Benjamins Publishing Company.

Huang, H.-H., & Lin, Y.-H. (2016). When unnecessary repairs become necessary: the case of nasal insertion in Standard Mandarin loanwords. In A. Albright & F. A. Fullwood (Eds.), *Proceedings of the 2014 Annual Meeting on Phonology*. Linguistic Society of America. http://doi.org/http://dx.doi.org/10.3765/amp.v2i0.3776

Lin, Y.-H. (2008a). Patterned Vowel Variation in Mandarin Loanword Adaptation : Evidence from a Dictionary Corpus. In Marjorie K.M. Chan & H. Kang (Eds.), *Proceedings of the 20th North American Conference on Chinese Linguistics (NACCL-20)* (Vol. 1, pp. 175–187). Columbus, OH.

Lin, Y.-H. (2008b). Variable vowel adaptation in Standard Mandarin loanwords. *Journal of East Asian Linguistics*, *17*(4), 363–380.

Lin, Y.-H. (2011). Loanword adaptation in Standard Mandarin and phonological theory. In Y. Xiao, L. Tao, & H. L. Soh (Eds.), *Current issues in Chinese linguistics* (pp. 426–451). Newcastle upon Tyne: Cambridge Scholars Publishing.

Lin, Y.-H. (2012). Variation in Standard Mandarin Loanword Adaptation. In *The 27th Annual Conference of International Association of Chinese Linguistics (IACL)*. Hong Kong.

Smith, J. L. (2006). Loan phonology is not all perception: Evidence from Japanese loan doublets. *Japanese/Korean Linguistics*, *14*, 63–74.

Yip, M. (1993). Cantonese Loanword Phonology and Optimality Theory. *Journal of East Asian Linguistics*, *2*(3), 261–291.

新英漢辭典 [A New English English-Chinese Dictionary]. 1988. Seattle: University of Washington Press.