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Interlanguage Phonology and Accentedness: An Experimental Study of Thai Final Nasal Consonants in Chinese Students Learning Thai

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Abstract

This paper provides an experimental study of interlanguage phonological characteristics of Chinese students learning Thai as a foreign language and the accentedness perceived by native Thai speakers. Both production and perception experiments were designed to see how Chinese students acoustically produced Thai final nasal consonants and how Thai native speakers perceived these Chinese-accented nasals. The production experiment compared the acoustic features of Thai final nasal consonants (i.e. /m/, /n/, and /ŋ/) produced by Chinese students and native Thai speakers (n = 5 in each group), who provided speech samples from a wordlist reading task, consisting of 28 words (840 tokens). Nasal acoustic properties of 840 tokens (duration, nasal murmurs, and formant transitions) were examined. The findings showed that the Chinese students produced significantly longer nasal duration and more drastic formant transitions compared to the native speakers. The perception experiment analyzed how native Thai raters (n = 10) rated speech samples concerning degrees of accentedness by using a 5-point Likert scale with 5 as the most native level. Based on this, the native Thai raters rated the Chinese students' speech as 3.22 on average, while native Thai speech was judged with an average score of 4.65, which demonstrated that native Thai raters could distinguish foreign speech from those pronounced by native speakers. To find out to what extent nasal acoustic characteristics in Chinese students' interlanguage phonology contributed to the degree of accentedness, stepwise regression analyses were utilized to discover that nasal duration was particularly important in accurately predicting accentedness in Thai with Chinese accents.

INTRODUCTION

After it was coined by Larry Selinker in the 1970s, interlanguage has become one of the central research interests in the field of second language acquisition or foreign language learning

(Tarone, 2018). The system of interlanguage, according to Selinker (1972), is considered a distinct linguistic system that is independent of both learner's native language and the target language. This linguistic system constructed by language learners encompasses not only phonological, morphological, and syntactic levels, but also interlanguage lexicon, pragmatics, discourse, etc. Among various aspects of the interlanguage system, interlanguage phonology is probably one of the most notable features because it has been proved that no matter how fluent we become and how native-like lexical or syntactic production is, we will retain some phonological features that distinguish us from native speakers (Flege & Port, 1981; Oyama, 1976; Patkowski, 1990; Saito et al., 2019). These interlanguage phonological traits are also known as the phenomena of foreign accents (Jenner, 1976; Osatananda & Salarat, 2020), defined as accentedness by Munro and Derwing (1995).

When dealing with foreign accents, the first question to ask is what the nature of foreign accents is. Given this, many studies have been conducted to find out the acoustic resources of foreign accents. Based on previous findings, foreign accents can be linked to vowels, consonants, and some other suprasegmental features of foreign speech, such as tones, stress, and intonation. In terms of vowels in foreign language speech, Munro (1993) analyzes ten English vowels in the syllable structures /bVt/ and /bVd/ produced by Arabic native speakers in terms of vowel durations, the first and second formant frequency (F1 and F2) of the vowel's acoustic properties, and its F1 and F2 movement. Compared to native English speakers, Arabic speakers differ on at least one of these acoustic parameters for every vowel studied. Unstressed vowels in English produced by Korean-English bilinguals are explored in another study by Lee et al. (2006). In comparison to native English speakers, Koreans have a smaller intensity difference and a shorter duration difference between unstressed and stressed vowels. In addition to vowels, other researchers are interested in consonants in interlanguage phonology. Cantonese speakers fail to pronounce certain English initial consonant clusters, especially those involving a liquid, according to Chan (2006). Final consonant clusters with voiced obstruents (e.g., /bd/, /vz/) are more difficult to pronounce than those with voiceless obstruents for native Vietnamese speakers, according to Nguyen (2008). Riney et al. (2000) look at the English liquids /r/ and /l/ and discover that the substitution of flap /r/ for English liquids is a distinguishing feature of interlanguage phonology constructed by Japanese speakers learning English as a foreign language. By studying Korean-accented English, Chung and Kim (2021) find that Korean-English speakers' English /l/ has significantly lower F2-F1 values than /l/ in Korean, but significantly higher F2-F1 values than /l/ produced by native English speakers. And the deviations in English liquids in Korean-accented English are negatively correlated to the degree of accents. Kang and Moran (2014) identify the types of phonological errors that affect raters' judgments in determining English language oral proficiency. Some consonant substitutions, such as /ʃ/ for /z/ (*vishit for visit), /b/ for /p/ (*berson for person), or /t/ for /d/ (bat* for bad), are found to be closely related to the degree of English oral proficiency. Idemaru et al. (2019) look at how F1 and F2 of vowels, VOT of stops, and other features in Chinese- and English-accented Japanese affected the degree of accentedness. The tone is found to be an important factor in predicting accents in Japanese.

As previously indicated, several investigations have established the importance of interlanguage phonological characteristics in accentedness (Crowther et al., 2018; Li & Chen, 2019; Saito et

al., 2019). They come to the conclusion that some segmental elements in interlanguage phonological system are closely related to the degree of accentedness as perceived by native speakers. The majority of the prior studies' findings, on the other hand, are based on investigations in varied accented English. Other than English, there has not been much research done on other languages. Studies on the interaction of interlanguage phonological characteristics and accentedness in foreign-accented Thai are especially few. Wayland (1997) seems to be one of the few researchers that attached importance to this issue and investigates the acoustic differences between native Thai speakers and foreign language speakers by examining Thai vowels, consonants, and tones produced by native English speakers. Acoustic differences are discovered in temporal (i.e., VOT, vowel duration) and spectral (i.e., F1, F2, F2-F1, and fundamental frequency) dimensions. The findings reveal that native English speakers' Thai production does not significantly differ from native Thai speakers in terms of temporal dimensions, but they have more deviated speech in terms of vowel formants and fundamental frequency which gave rise to the perception of vowel quality and tones, respectively. Moreover, the results of the accentedness rating reveal that only some tones are reliable predictors for accentedness in English-accented Thai.

In the context of Chinese students learning Thai, they are also proven to encounter many accent problems when speaking Thai. However, most of the studies addressing Chinese students learning Thai are conducted in an impressionistic manner, instead of providing acoustic evidence. Among these scarce acoustic studies dealing with the acquisition of Thai by native Chinese speakers, Le (2017) acoustically compared Thai vowels produced by three groups of Chinese speakers, namely, Tai Lue, Naxi, and Yunnanese. She discovered that all three groups of Chinese speakers did not distinguish vowel length as clearly as native Thai speakers, while Tai Lue speakers pronounced more standard Thai vowels in terms of vowel quality. Apart from vowels, final nasal consonants seem to be another challenge for Chinese speakers of Thai. Juwarahawong (2000) discovers that Teochew people living in Thailand exhibit different final consonant articulations. In the final position, they have difficulties discriminating between the alveolar and velar nasal consonants. Lianghiranthaworn and Chapoo (2019) analyze the pronunciation problems of Chinese students studying Thai as a foreign language and discover that Chinese students produce final nasal consonants with a low accuracy rate. Hou (2019) finds out that Chinese students commit some spelling errors while writing the bilabial, alveolar, and velar nasal consonants in a final position, which might result from misarticulation when pronouncing these three final nasal consonants. Even though the studies mentioned here have pointed out that Chinese speakers of Thai have pronunciation problems with Thai final nasal consonants, none of them acoustically elaborate on what the problems are, and it remains unclear if the problems in pronouncing Thai final nasal consonants damage the cross-language communication between Chinese and Thai native speakers. Therefore, the analysis of acoustic features of Chinese-accented final nasal consonants and the test of the perception of native Thai speakers are extremely necessary.

Based on the literature reviewed above, it remains unclear how different Chinese learners acoustically produce Thai final nasal consonants, and to what degree these pronunciation deviations in Chinese students' interlanguage phonological system can be a valid predictor of accentedness. Therefore, the objectives of the current study are twofold, 1) to compare the

acoustic differences in nasal final consonants produced by Chinese learners of Thai and native Thai speakers; 2) to find out to what extent these acoustic differences in final nasal consonants can be used as predictors of accentedness perceived by native Thai raters.

RESEARCH METHODOLOGY

The present study compared acoustic features of final nasal consonants in Thai, namely, nasal duration (the duration between the onset and offset of the weak low-frequency formants of nasal consonants), nasal murmurs (arising from resonance in the nasal cavity, and are found to be potential cues in differentiating the places of articulation), and formant transition (formant differences between the adjacent vowel and nasal consonant, and have been proven to be effective cues in distinguishing the place of articulation for nasals, especially with respect to the second formant), produced by native Thai speakers and Chinese students of Thai, and further determined to what extent these acoustic differences were correlated to the degree of accentedness perceived by native Thai. Therefore, the experiment of the current study was split into two sections. The production experiment involves an acoustic analysis of the interlanguage phonology in Thai nasal consonant productions pronounced by Chinese students compared with those of Thai native speakers. On the other hand, the perception experiment involves an accentedness analysis of Chinese students based on native Thai speakers' perception of Thai nasal consonants.

Production experiment: Interlanguage phonological characteristics analysis

Participants

Five Chinese speakers learning Thai as a foreign language and 5 native Thai speakers provided speech samples for the current study. Age and gender were controlled to reduce the impact on acoustic properties in speech samples. Thus, all the speakers for the current study were females. The average age of Chinese speakers was 20 (range: 19-22). They were recruited from the Thai Language Department, at Xi'an International Studies University. At the point of the research, they had been majoring in Thai for three years at the undergraduate level. According to their GPA in the Thai language courses, their Thai language proficiency reached an intermediate level. Based on their self-report, they all originated from the Shaanxi Province, China, and Mandarin Chinese was the only predominant language in their daily life. At the same time, they also used Central Plains Mandarin as their dialect with a neglectable portion. Serving as the control group, all 5 native Thai speakers who provided speech samples were from Bangkok. Their mean age was 19.8 (range: 18-21). All reported the use of Bangkok Thai on a daily basis.

Speech material

Speakers were asked to read the following wordlist (Table 1) including potentially problematic vowels for Chinese students (Le, 2016). In her study, Chinese students showed more deviated patterns when pronouncing Thai vowels /e/, /ɛ/, /ɨ/, /ə/, /ɔ/, /o/ and their long counterparts compared to other vowels. Each selected vowel was combined with the three final nasal

consonants, namely, /m/, /n/, and /ŋ/. All the selected words comprised of vocabulary used in real life and no pseudo word was included. Totally, 28 words were selected as target words for analysis. They were further divided into four separate groups. Besides, 12 words (3 for each group) that did not have a final nasal consonant were also listed to obscure the objectives of this study. All the target words were read in a carrier sentence three times for each participant: พูดคำว่า___ สามครั้ง /pʰûːt kʰam wâː _____ săːm kʰráŋ/ (Say the word _____ three times). In total, there were 840 tokens for the current study (28 words × 10 informants × 3 times = 840). The whole recording session was conducted in a quiet room by using the digital software, PRAAT (Boersma & Weenink, 2023).

Table 1
Wordlist

Group 1	Group 2	Group 3	Group 4
เอ็น /ʔen/ 'ligament'	เกม /keːm/ 'game'	โต /toː/ 'big'	แกร็น /krɛn/ 'dwarfed'
เกณฑ์ /keːn/ 'criterion'	กาก /kàːk/ 'garbage'	แพง /pʰɛːŋ/ 'expensive'	บอก /bɔ̀ːk/ 'tell'
โคม /kʰoːm/ 'lamp'	จบ /còp/ 'end'	แจว /cɛːw/ 'oar'	หอม /hɔ̌ːm/ 'fragrant'
ตี /diː/ 'good'	ดึง /dɨŋ/ 'pull'	ก้อน /kɔ̂ːn/ 'lump'	เต็ม /tem/ 'full'
ขึ้น /kʰɨ̂n/ 'go up'	ปืน /pɨːn/ 'gun'	ยืม /yɨːm/ 'borrow'	แน่น /nɛ̂ːn/ 'tightly'
คบ /kʰóp/ 'associate with'	เต็ง /teŋ/ 'favorite'	เอง /ʔeːŋ/ 'only'	นอก /nɔ̂ːk/ 'outside'
เดิน /dəːn/ 'walk'	หม่ม /hòm/ 'cover'	ทุก /tʰúk/ 'every'	แข็ง /kʰɛ̌ŋ/ 'hard'
โดน /doːn/ 'bump against'	เพิ่ม /pʰɤ̂ːm/ 'add'	จง /coŋ/ 'must'	แถม /tʰɛ̌ːm/ 'add'
เริง /rəːŋ/ 'joyful'	จอง /cɔːŋ/ 'reserve'	ซึม /sɨm/ 'seep'	โกง /koːŋ/ 'cheat'
ไอ /ʔaj/ 'cough'	สาด /sàːt/ 'splash'	ปน /pon/ 'mix'	เร็ว /rew/ 'fast'

Acoustic analyses

The acoustic measurements examined in the current study included nasal duration, nasal murmurs (nasal formant 1, nasal formant 2, and nasal formant 3, NF1, NF2, and NF3, hereafter), and formant transitions (F1, F2 transitions), which were conducted by using PRAAT software (Version 6.2.14). The whole acoustic analysis session contained 3 steps, as shown below.

Step 1: Duration of final nasal consonants was counted from the point where the nasal murmurs began with the first periodic pulse to the end of the nasal consonants. The analyzed timing property was converted from second to millisecond (ms). As shown in Figure 1, the duration of /m/ in /keːm/ was measured as 0.226887 seconds, and then, this property was multiplied by 1,000 to be 226.887 milliseconds.

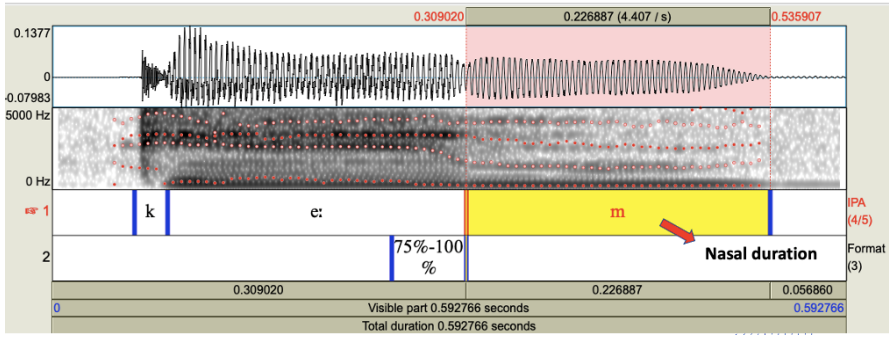


Figure 1 Duration of nasal /m/ in /ke:m/

Step 2: Nasal murmurs included the mean values of NF1, NF2, and NF3, which were calculated from the onset to the offset of the nasal consonants, as demonstrated in Figure 2.

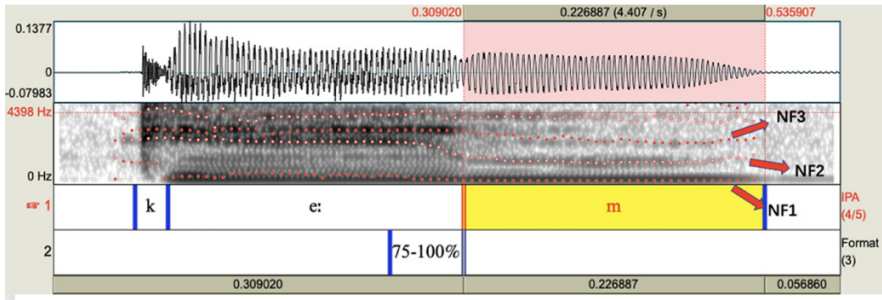


Figure 2 Nasal murmurs of /m/ in /ke:m/

Step 3: The calculation of formant transition is shown in Figure 3, which was defined as formant frequency between vowels and nasal final consonants, i.e. the difference values of F1 and F2 from 75% to 100% of the vowels, which demonstrated how the following nasal consonant influenced the vowel.

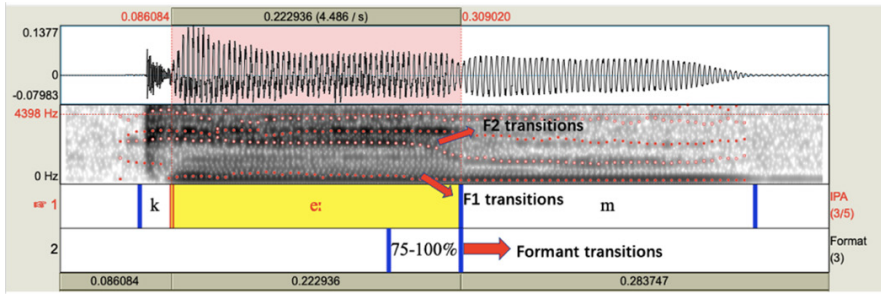


Figure 3 Formant transitions of nasal /m/ in /ke:m/

After the three-step acoustic analyses, the acoustic properties mentioned above of both native Thai speakers and Chinses students were summarized respectively, and students' *t*-tests were used to find out whether the three acoustic features, namely, nasal duration, nasal murmurs, and formant transitions, were significantly different between the two groups of participants.

Perception experiment: An accentedness analysis in Chinese students

In the perception experiment, speech samples collected from the production experiment were submitted to an accentedness rating test. As defined by Munro and Derwing (1995), listeners' assessments of how closely a pronunciation resembles that of a native speaker are commonly defined as accentedness. Although the process is not fully understood, it is probable that native speakers utilize an abstract prototype for comparison when evaluating foreign-accented speech. The prototype serves as the standard form of a certain phoneme. Native raters compare the foreign speech that they hear to the prototype in their minds. Depending on the degree of the difference, foreign-accented speech may be judged as having varying degrees of foreign accents (Flege, 1995; Munro, 1993; Wayland, 1997).

Perception material

In the present study, 10 native Thai raters participated in the accentedness rating task. None of these raters provided speech samples in the production experiment so that the raters did not have to rate their own pronunciation. The raters were on average 21.8 years old (range: 18-35). Since raters' social factors, such as gender and age, do not play a decisive role in accentedness judgment, gender and age were not strictly controlled in the present study. A 5-point Likert scale (1= very strong Chinese accent, 5 = no Chinese accent at all) was used to rate the degree of accentedness. For example, if the raters found the Thai word that they heard to be moderately accented, they might rate it as 3 according to their holistic impression. Before the actual rating, a practice session was conducted by the researcher to make sure that the listeners understood the concept of accentedness. All the Thai words collected in the production experiment were set into 10 word-groups by randomly picking up 3 words pronounced by each speaker so that each word-group contained target words from all 10 speakers in random order. In each word-group, the researcher designed it to contain 28 words containing a final nasal consonant, and 2 words that did not end up with a nasal consonant to hide the objectives of the rating task, yielding a total of 300 stimuli (30 words × 10 word-groups = 300) for each listener. An excerpt of the rating sheets was provided in Table 2.

Table 2

Test sheet for the perception experiment

	1	2	3	4	5
	มีสำเนียงจีนหนักมาก (Very strong Chinese accent)	มีสำเนียงจีนหนัก (Strong Chinese accent)	มีสำเนียงจีนปานกลาง (Moderate Chinese accent)	มีสำเนียงจีนนิดหน่อย (Slight Chinese accent)	ไม่มีสำเนียงจีนเลย (No Chinese accent at all)
1.ก้อน 'lump'					
2.แถม 'add'					
3.จอง 'reserve'					
4.แน่น 'tight'					

	1	2	3	4	5
	มีสำเนียงจีนหนักมาก (Very strong Chinese accent)	มีสำเนียงจีนหนัก (Strong Chinese accent)	มีสำเนียงจีนปานกลาง (Moderate Chinese accent)	มีสำเนียงจีนนิดหน่อย (Slight Chinese accent)	ไม่มีสำเนียงจีนเลย (No Chinese accent at all)
5.แกร็น 'dwarfed'					
...					
9.แจว 'oar'					
...					
22.นอก 'outside'					
...					
29.โกง 'cheat'					
30.เกณฑ์ 'criterion'					

The raters received a rating sheet containing 10 word-groups and each word-group contained 30 target words in standard Thai scripts and 5 blocks for accentedness rating, as shown in Table 2. The whole process of perception took place online and participants were required to sit in a quiet room. Raters listened to all the target words only once and made a holistic judgment according to their intuitions, and there was a 3-second interval between two words controlled by the researcher. Between two word-groups, there was also a 10-second interval until all the ten word-groups were rated. Before the rating session, the raters were reminded to inform the researcher if they encountered any hearing problems due to poor Internet connection. None of the participants had reported any hearing problem during the whole rating session so it could be assumed that the rating session was conducted smoothly.

In order to assess whether the 10 native raters consistently rated speech samples and whether any of them differed significantly, inter-rater reliability was calculated (Cronbach's α, $p < .001$). According to the results of Cronbach's alpha analysis, high reliability for 5-point accentedness ratings was identified among 10 Thai raters ($\alpha = .95$).

After the rating session, a series of correlation analyses were conducted to find out whether or not acoustic properties in the production experiment were correlated with the accentedness rating results, in which all the acoustic measurements that were significantly different between the two groups of speakers were used as the dependent variables, while accentedness rating scores were set as the independent variable. Furthermore, if there was a correlation between any acoustic property and accentedness rating results, a stepwise regression analysis would be utilized to find out the effect size of the correlated acoustic feature in accentedness rating.

RESULTS

In the following sections, results of the production experiment and perception experiment are presented separately. In the production experiment, acoustic features of nasal final consonants produced by native Thai speakers and Chinese students, namely, duration, nasal murmurs, and formant transitions, are compared, and those that are significantly different are highlighted, including nasal duration and formant transitions. While in the perception experiment, native raters were able to successfully distinguish between Chinese speakers of Thai and native Thai speakers. Furthermore, acoustic features identified in the production experiment are found to be correlated to the rating score. Finally, a series of stepwise regression analyses determine that nasal duration differences might be the most robust predictor in Chinese-accented Thai as perceived by native Thai raters.

Production experiment: Interlanguage phonological characteristics of Chinese students

Duration

As shown in Figure 4, Chinese speakers of Thai acoustically produce different final nasal consonants compared to native Thai speakers in terms of nasal duration, i.e., they consistently pronounce longer final nasal consonants than those of native Thai speakers in all three final nasal consonants. The average length of nasal final consonants pronounced by Chinese students is 210 ms, whereas native Thai speakers produce a much shorter length of nasal consonants, which is 140 ms. Meanwhile, in both Chinese and Thai speech samples, the velar nasal /ŋ/ has the longest duration among the three final nasal consonants in Thai: 230 ms for Chinese students and 150 ms for native Thai speakers, respectively. In addition, the bilabial nasal /m/ is the shortest in both native Thai speakers and Chinese students, which is 130 ms and 190 ms in length. The alveolar nasal /n/ pronounced by both groups of speakers has a medium length.

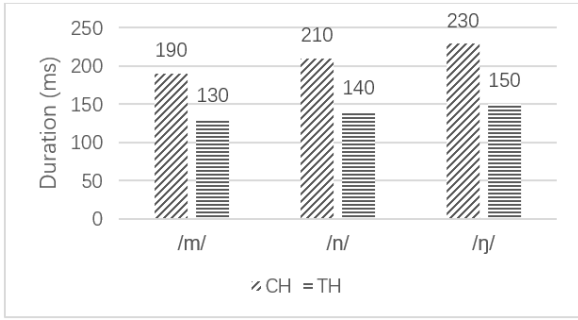


Figure 4 Duration of final nasal consonants /m/, /n/, and /ŋ/

A series of Student's t-tests are utilized to determine whether the duration of nasal final consonants produced by both Chinese students and native Thai speakers are significantly different, and the results are presented in Table 3. As mentioned earlier, Chinese speakers of Thai pronounce longer final nasal consonants and they differ significantly compared to those produced by native Thai speakers, according to Table 3. Among these, the duration of bilabial nasal /m/ is significantly different between Chinese students and native Thai speakers

[t(8) = 8.744, p < .01]. The results also reveal a significant difference in alveolar /n/ [t(8) = 6.396, p < .01] and velar /ŋ/ [t(8) = 5.143, p < .01] nasal consonants in Thai. In terms of the standard deviation of nasal duration, Table 3 shows that Chinese students' nasal duration is greater, which proves that Chinese students produce final nasal consonants in a more inconsistent manner in duration compared to native Thai speakers.

Table 3

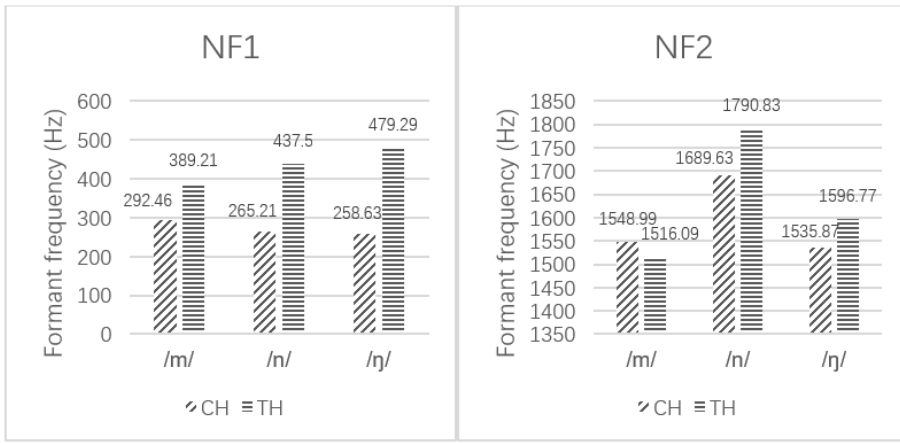
Results of students' *t*-tests in the duration of final nasal consonants

Measurements	Speakers (Mean ± SD)		*t*	*p*
	CH (*n* = 5)	TH (*n* = 5)		
Duration /m/	190 ± 10	130 ± 10	8.744	.000**
Duration /n/	210 ± 20	140 ± 20	6.369	.000**
Duration /ŋ/	230 ± 30	150 ± 10	5.143	.001**

* p < .05, ** p < .01

Nasal murmurs

In contrast to nasal duration, nasal murmurs, including NF1, NF2, and NF3, in final nasal consonants show little systematic consistency, as demonstrated in Figure 5 below. In NF1, native Thai speakers have greater formant frequency in /m/, /n/, and /ŋ/. However, when comparing the formant frequency of /m/, /n/, and /ŋ/ of the two groups of participants, the highest to lowest frequency values for NF1 of native Thai speakers run from /ŋ/ through /n/ to /m/, which is consistent with the findings of Ohala (1975). On the other hand, formant frequency values of the three nasal consonants produced by Chinese students demonstrate an exactly opposite tendency. In NF2, the formant frequency of native Thai speakers is higher than Chinese speakers of Thai in /n/ and /ŋ/, but lower in /m/. Finally, Chinese speakers have higher values in NF3 of /m/ and /n/, but lower values in /ŋ/. Student's t-tests are also used to find out whether these differences in formant frequency are significant or not.



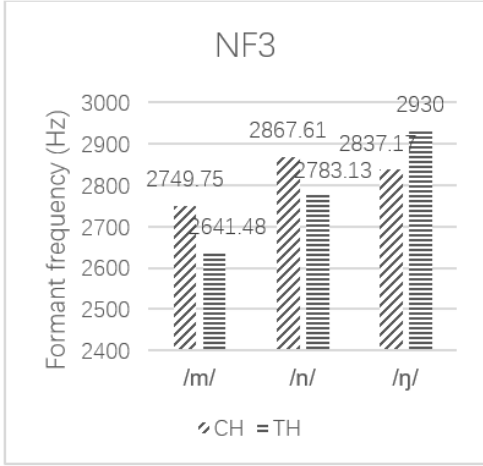


Figure 5 Nasal murmurs of final nasal consonants /m/, /n/, and /ŋ/

After a set of students' *t*-tests, it can be concluded from Table 4 that when the nasal consonants are in the final position of a Thai word, the differences in NF2 and NF3 of all the three nasals and NF1 of /m/ between Chinese learners of Thai and native Thai speakers are not significant, which means that the two groups of participants produced overall similar final nasal consonants in Thai in terms of nasal murmurs. On the other hand, NF1 of native Thai speakers and Chinese students seems to be a distinguishing factor that sets them apart because NF1 values of /n/ and /ŋ/ between them differentiate significantly at t(8) = -4.274, $p < .05$, and t(8) = -5.011, $p < .01$, respectively.

Table 4
Results of students' *t*-tests in nasal murmurs of nasal final consonants

Measurements	Speakers (Mean ± SD)		*t*	*p*
	CH (*n* = 5)	TH (*n* = 5)		
NF1 /m/	292.46 ± 41.77	389.21 ± 88.16	-2.218	.057
NF1 /n/	265.21 ± 11.10	437.50 ± 89.46	-4.274	.012*
NF1 /ŋ/	258.63 ± 18.02	479.29 ± 96.80	-5.011	.001**
NF2 /m/	1548.99 ± 123.66	1516.09 ± 163.52	.359	.729
NF2 /n/	1689.36 ± 115.12	1790.83 ± 96.08	-1.513	.169
NF2 /ŋ/	1535.87 ± 122.13	1596.77 ± 182.38	-.62	.552
NF3 /m/	2749.75 ± 383.27	2641.48 ± 286.46	.506	.627
NF3 /n/	2867.61 ± 111.55	2783.13 ± 268.24	.65	.542
NF3 /ŋ/	2837.17 ± 113.52	2930.00 ± 158.72	-1.064	.319

* $p < .05$, ** $p < .01$

Formant transitions

As presented in Figure 6, formant transitions in F1 of both Chinese and native Thai speakers demonstrate a minus value in all /m/, /n/, and /ŋ/, and the values of Chinese learners of Thai clearly surpass those of native Thai speakers. The average values in F1 transitions of Chinese

students are 123.3 Hz, while it is 43.76 Hz for native Thai speakers. In terms of formant transitions in F2, although it shows either minus or plus tendency among /m/, /n/, and /ŋ/, there are still obvious differences in formant frequency between Chinese learners and native Thai speakers. For /m/, both Chinese students and Thai have minus F2 transition values and the values of Chinese students are almost tripled compared to those of native Thai speakers. On the other hand, /n/ and /ŋ/ demonstrate even wider discrepancies, in which Chinese students have minus F2 transition values, whereas native Thai speakers show plus values.

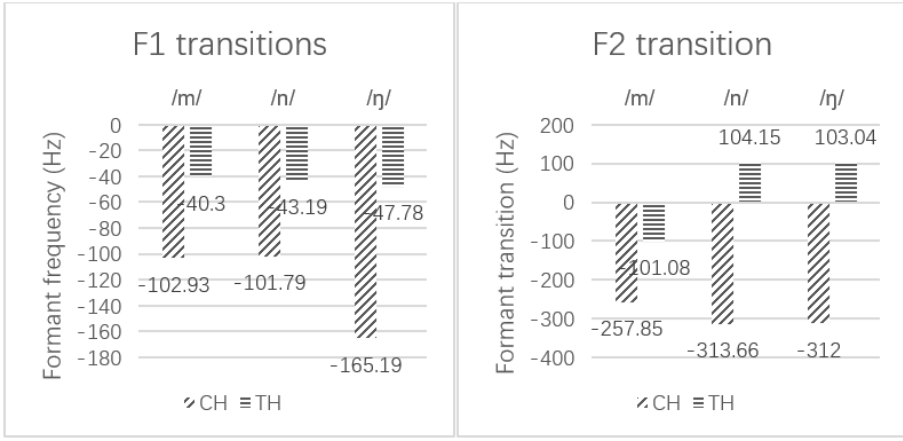


Figure 6 Formant transitions of final nasal consonants /m/, /n/, and /ŋ/

The students' *t*-tests in formant transitions of final nasal consonants reveal that formant transitions in F1 and F2 could be considered robust measurements to distinguish Chinese speakers of Thai from native Thai speakers, since the differences in formant transitions in F1 and F2 of all three nasals reach a significant level (Table 5), especially in F1 transitions of /m/, /ŋ/ and F2 transitions of /ŋ/ ($p < .01$). As mentioned earlier, all acoustic differences in formant transitions between Chinese students and native Thai speakers reach a significant level, which demonstrates that Chinese students learning Thai as a foreign language have more exaggerated formant transitions than native speakers. In other words, nasal final consonants in Thai articulated by Chinese students have more impact on adjacent vowels in Thai words.

Table 5

Results of students' *t*-tests in formant transitions of final nasal consonants

Measurements	Speakers (Mean ± SD)		*t*	*p*
	CH (*n* = 5)	TH (*n* = 5)		
F1 transition /m/	-102.93 ± 126.50	-20.30 ± 70.54	-1.276	.001**
F1 transition /n/	-226.10 ± 112.35	-43.19 ± 65.80	-3.141	.014*
F1 transition /ŋ/	-165.19 ± 58.34	-47.78 ± 28.20	-4.052	.004**
F2 transition /m/	-257.85 ± 97.53	-101.08 ± 60.23	-3.058	.016*
F2 transition /n/	-226.10 ± 112.35	-43.19 ± 65.80	-3.141	.014*
F2 transition /ŋ/	-165.19 ± 58.34	-47.78 ± 28.20	-4.052	.004**

* $p < .05$, ** $p < .01$

Production experiment: Summary and discussion

Generally speaking, Chinese learners of Thai produce nasal final consonants in the production experiment differently when compared to native Thai speakers. The acoustic analysis of Chinese-accented Thai final nasal consonants reveals a wide range of temporal and spectral systematic features, the bulk of which could be connected in some manners to Chinese learners' interlanguage phonology when learning Thai. Among the examined acoustic measurements, there are only some slight differences in nasal murmurs, and the majority of these differences are not statistically significant. Nasal duration and formant transitions, on the other hand, are discovered to be better traits that distinguish Chinese speakers of Thai from native Thai speakers. More specifically, Chinese students pronounce Thai final nasal consonants for a longer duration than native speakers do. In addition, the final nasal consonants articulated by Chinese speakers also demonstrate a more drastic change in the transition phase between vowels and final nasal consonants. Thus, longer nasal duration and more drastic formant transitions could be considered two of the most important features in interlanguage phonology of Chinese learners of Thai.

It is also notable that in the production experiment, four acoustic measurements of /n/ and /ŋ/, namely, nasal duration, NF1, and formant transitions in F1 and F2, are significantly different between Chinese students and native Thai speakers, while there is a total of three acoustic measurements that are significantly different between the two groups of speakers in pronouncing /m/, including nasal duration, formant transitions in F1 and F2, which suggests that Chinese students have produced /m/ in a more native manner. From the perspective of language transfer, Chinese speakers are supposed to have fewer difficulties pronouncing the final nasal /n/ and /ŋ/ in Thai since they positively transfer these two existing phonemes from their native language. However, the findings of the current study are inconsistent with this assumption. From another point of view, such as the Speech Learning Model (Flege & Port, 1981), which believes that foreign language sounds that also exist in the native language sound system are more difficult to learn than those that are new to learners. In the present study, /n/ and /ŋ/ exist in Chinese phonology as phonemic codas, whereas /m/ can only occur at the onset of a syllable. Compared to the new phoneme /m/, the similar /n/ and /ŋ/ cause more problems for Chinese students when learning Thai.

Perception experiment: An accentedness perception of Thai native speakers

Accentedness rating results

The accentedness perception results of each speaker are presented in Table 6, which gives the mean rating scores obtained from averaging the scores rated by all 10 native Thai listeners on target words that contain either a bilabial /m/, alveolar /n/, or velar /ŋ/ final nasal consonant. As a whole, the mean score for native Thai speakers is 4.65 (ranging from 4.37 to 4.87), which means that most of the Thai words articulated by native Thai speakers are judged to be at the native level. For Chinese speakers of Thai, on the other hand, the mean score is 3.22 (ranging from 2.92 to 3.92). On average, the mean degree of accentedness for the non-native group is 1.43 lower than that for native speakers.

Table 6

Accentedness rating scores for each speaker

Speakers	/m/	/n/	/ŋ/
CH1	3.34	3.03	3.58
CH2	3.45	2.75	2.68
CH3	3.33	3.42	2.93
CH4	3.92	3.25	3.08
CH5	3.57	2.92	3.13
Mean	***3.52***	***3.07***	***3.08***
TH1	4.67	4.58	4.73
TH2	4.58	4.78	4.5
TH3	4.63	4.87	4.37
TH4	4.6	4.62	4.72
TH5	4.82	4.87	4.45
Mean	***4.66***	***4.744***	***4.55***

To put it another way, Figure 7 shows the comparison between the rating scores of Chinese and Thai groups. Native Thai speakers receive higher scores from the raters in all three final nasal consonants. Separately, the bilabial consonant /m/ receives the lowest accentedness score, whereas /n/ and /ŋ/ are judged to be more accented among Chinese learners of Thai. As mentioned in the previous sections, /n/ and /ŋ/ are similar sounds in Chinese and Thai phonological systems, while /m/ in the coda position is a new phoneme for Chinese students learning Thai. The findings in the Perception Experiment are consistent with what the Speech Learning Model claims: foreign language sounds that also exist in the native language sound system are more difficult to learn than those that are new to learners.

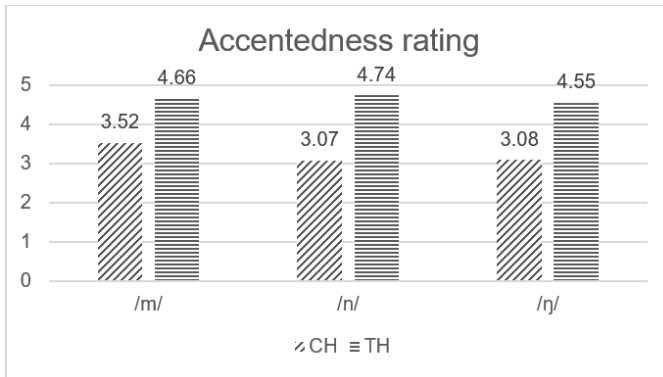


Figure 7 Accentedness rating results for /m/, /n/, and /ŋ/

Correlation analyses

In this section, the results of the production experiment and perception experiment are combined to examine the extent to which the acoustic differences between the non-native group and the native group could be correlated to the accentedness rating scores assigned by

native raters. In the correlation analyses, all the acoustic measurements that are significantly different between the two groups of speakers are used as the dependent variables, while accentedness rating scores are set as the independent variable. Table 7 reports statistically significant correlations. As mentioned in the results of the production experiment, there are totally 11 acoustic features that are significantly different between the two groups of participants. All of them are found to be correlated to accentedness rating ($p < .05$), as illustrated in Table 7.

Table 7

Results of correlation between acoustic measurements of nasal final consonants and accentedness rating

Measurements	Correlation Coefficient	*p*
Duration of /n/	-.911**	.000
Duration of /m/	-.937**	.000
Duration of /ŋ/	-.786**	.007
NF 1 of /n/	.846**	.002
NF 1 of /ŋ/	.836**	.003
F1 transition of /n/	.638*	.047
F1 transition of /m/	.821**	.001
F1 transition of /ŋ/	.643*	.045
F2 transition of /n/	.851**	.002
F2 transition of /m/	.741*	.014
F2 transition of /ŋ/	.691*	.027

* $p < .05$, ** $p < .01$

Stepwise regression analyses

To determine which acoustic parameters contribute to a foreign accent in Chinese-accented Thai perceived by native Thai speakers, multiple regression analyses are separately conducted on the three final nasal consonants to find out the most robust predictors. All acoustic parameters of the target words measured in the production experiment that are significantly correlated with accentedness are used as predictors in the stepwise linear multiple analysis, with the mean accentedness rating scores being the dependent variable. For the bilabial final nasal, duration, formant transitions in F1 and F2 are predictor variables. For alveolar and velar nasals, duration, NF1, and formant transitions in F1 and F2 are predictor variables. The results of stepwise regression analyses of acoustic predictors in accentedness rating are reported in Table 8.

Table 8

Results of stepwise regression analyses of acoustic predictors in accentedness rating

Nasal consonants	Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
/m/	1	.868a	.753	.722	.42928
	2	.939b	.881	.847	.31863
	a Predictors: duration				
	b Predictors: duration, F1 Trans				
/n/	1	. 911a	.831	.809	.39406
	a Predictors: duration				
/ŋ/	1	. 925a	.856	.838	.32764
	a Predictors: duration				

The results in Table 8 show that two models are constructed for the bilabial nasal /m/. In Model 1, duration is the only predictor variable, and it could explain 75.3% of the variance in accentedness rating according to the R Square value. In Model 2, formant transitions in F1 are added as another predictor variable, and the whole model explained 88.1% of the variance in accentedness rating. Thus, nasal duration seems to be the most effective predictor in accentedness rating for the final nasal consonant /m/, which accounts for 75.3% of the variance in foreign accent perception, whereas formant transitions in F1 account for an additional 12.8% of the variance. At the same time, formant transition in F2, which is also significantly correlated to accentedness, is excluded since the coefficient was no longer statistically significant in this multiple regression analysis.

Similarly, the acoustic measurements that are significantly correlated to accentedness rating for the alveolar /n/ and velar /ŋ/ are also used as predictor variables to determine the contributions of these acoustic measurements in accentedness perceived by native Thai speakers. As shown in Table 6, nasal duration is the only significant predictor for these two final nasals, which accounts for 83.1% and 85.6% of the variance in accentedness rating, respectively.

Perception experiment: Summary and discussion

In summary, native Thai raters in the perception experiment successfully distinguished speech samples produced by non-native speakers from those of native Thai speakers, even though they just listened to isolated words instead of continuous speech. Native speakers compared the foreign speech with the abstract prototype in order to give various degrees of accentedness according to the extent of the differences. As a result, the average accentedness rating score of Chinese learners of Thai is 3.22, while native Thai speakers are rated as 4.65.

To find out which acoustic properties contribute more to the accentedness rating, correlation, and regression analyses were used. In the correlation analysis, nasal duration and formant transitions are found to be the most strongly correlated acoustic parameters for all three nasal final consonants, whereas only NF1 of /n/ and /ŋ/ are significantly correlated to accentedness. In the next step, linear multiple regression analyses were conducted to explore the most effective predictors for accentedness. The correlation analyses show that nasal duration can account for the most of variance of accentedness rating and that other acoustic parameters are all excluded from the regression models, except formant transitions in F1 of /m/.

In this study, the results of the perception experiment demonstrate that native Thai speakers and speakers with Chinese accents produced final nasal consonants very differently. According to the perception and rating data, the native Thai raters were perceptive to these audible characteristics in Thai speech with a Chinese accent. The raters clearly differentiated between native Thai speech and speech samples produced by Chinese learners of Thai after realizing that the non-native speech samples accented in the majority of cases. When the rating scores were regressed on the acoustic parameters that were significantly correlated to accentedness perception, the results reveal that nasal duration, a temporal dimension of final nasal consonants, is the only significant predictor for accentedness rating.

CONCLUSION AND RECOMMENDATIONS

The objective of this paper was to add to our understanding the foreign-accented phenomenon. It examined how native and non-native Thai speakers produce three final nasal consonants in Thai, as well as how native Thai raters perceive speech productions pronounced by the two groups of speakers. The aims were to determine whether there are any acoustic differences in the production of these two groups of speakers, and if so, which of these acoustic differences influence the degree of accentedness perceived by native raters.

In the Chinese students' interlanguage phonology, there are two most prominent features in the acquisition of final nasal consonants in Thai, namely, longer nasal duration and more drastic formant transitions. These two features demonstrate that Chinese students and native Thai speakers differed in both temporal and spectral dimensions of final nasal consonants. Chinese speakers of Thai particularly show significantly longer nasal duration than native Thai speakers and more drastic formant transitions between vowels and final nasal consonants, which, as previously mentioned, may be the result of a negative transfer from their native tongues. The findings of the perception experiment are consistent with what had been discovered by the acoustic analyses. Both nasal duration and formant transitions are significantly correlated to the degree of accentedness as perceived by native Thai raters. Furthermore, it is discovered through the stepwise regression analysis that duration, as the temporal dimension of final nasal consonants, is the most reliable predictor for when native Thai speakers perceive Chinese-accented Thai.

The results of our study also provide some pedagogical implications for teaching Thai as a second language to Chinese students. First of all, the significance of final nasal consonants should be highlighted. It has been long assumed that these nasal consonants might not pose any learning difficulties for Chinese students because they exist in Chinese phonology. Instead, more effort was placed in teaching the three final stop consonants in Thai (/p/, /t/, and /k/) since they are new phonemes for Chinese students. Based on the findings, Chinese students' production of Thai final nasal consonants is still problematic from an acoustic perspective, and it contributes significantly to the Chinese accent when speaking Thai. Therefore, more pedagogical focus should be put on final nasal consonants. Moreover, a comparison between native languages and second languages is a frequently used method in learning and teaching second languages. The current study also points out that this kind of comparison is necessary for Chinese students when acquiring the Thai language. Thai final nasal consonants /n/ and /ŋ/ have their equivalents in the Chinese phonological system, whereas /m/ does not since it only occurs as an initial consonant in Chinese. Chinese students obviously produced more standard /m/ rather than /n/ and /ŋ/. What needs to be emphasized to Thai language teachers and students is that the similarities between the native language and the second language do not always facilitate learning, and differences do not always pose difficulties either.

For further recommendations, it is necessary to find out the underlying causes for the features of foreign accents after knowing what the natural features of foreign accents are. Based on the findings, a comparison of Chinese and Thai final nasal consonants would shed more light on Chinese-accented Thai and to explain why Chinese learners of Thai produce nasal durations

that are significantly longer or formant transitions that are more exaggerated than native Thai speakers. Additionally, the task effect should be taken into account. Hypercorrection in the wordlist reading task may be the cause of the acoustic differences between Chinese students and native Thai speakers. In order to determine if the types of tasks significantly affect Chinese students' interlanguage phonological productions, studies in continuous speech in Thai may be complementary.

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