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The acoustic measurement of English vowel duration regarding
final consonant voicing produced by L1 Thai speakers



An Independent Study Submitted in Partial Fulfillment of the
Requirements
for the Degree of Master of Arts in English as an International Language
Inter-Department of English as an International Language
GRADUATE SCHOOL
Chulalongkorn University
Academic Year 2022
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จุฬาลงกรณ์มหาวิทยาลัย
CHULALONGKORN UNIVERSITY

การวัดค่าระยะเวลาสระอันเนื่องมาจากความถี่ของพยัญชนะท้ายโดยผู้พูดชาวไทย



สารนิพนธ์นี้เป็นส่วนหนึ่งของการศึกษาตามหลักสูตรปริญญาศิลปศาสตรมหาบัณฑิต
สาขาวิชาภาษาอังกฤษเป็นภาษานานาชาติ สหสาขาวิชาภาษาอังกฤษเป็นภาษานานาชาติ

บัณฑิตวิทยาลัย จุฬาลงกรณ์มหาวิทยาลัย

ปีการศึกษา 2565

ลิขสิทธิ์ของจุฬาลงกรณ์มหาวิทยาลัย

Independent Study Title	The acoustic measurement of English vowel duration regarding final consonant voicing produced by L1 Thai speakers
By	Miss Chalita Taothong
Field of Study	English as an International Language
Thesis Advisor	Assistant Professor SUJINAT JITWIRIYANONT, Ph.D.

Accepted by the GRADUATE SCHOOL, Chulalongkorn University in Partial Fulfillment of the Requirement for the Master of Arts

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ชลิตา เต่าทอง : การวัดค่าระยะเวลาสระอันเนื่องมาจากความก้องของพยัญชนะท้ายโดยผู้พูดชาวไทย . (The acoustic measurement of English vowel duration regarding final consonant voicing produced by L1 Thai speakers) อ.ที่ปรึกษาหลัก : ผศ. ดร.ศุจินันท์ จิตวิริยพันธ์

งานวิจัยนี้เกี่ยวข้องกับปรากฏการณ์ของค่าระยะเวลาของสระอันเนื่องมาจากความก้อง และ ไม่ก้องของพยัญชนะท้ายในภาษาอังกฤษ (voicing effect) voicing effect คือปรากฏการณ์เมื่อค่าระยะเวลาสระที่นำหน้าเสียงก้องของพยัญชนะท้ายจะยาวกว่าค่าระยะเวลาสระที่นำหน้าเสียงไม่ก้องของพยัญชนะท้าย ในภาษาอังกฤษค่าระยะเวลาสระสามารถใช้เป็นสัญญาณบอกถึงเสียงก้องและไม่ก้องของพยัญชนะท้ายได้ งานวิจัยนี้มีวัตถุประสงค์เพื่อ 1) ศึกษาค่าระยะเวลาในภาษาอังกฤษที่นำหน้าเสียงก้องและไม่ก้องของพยัญชนะท้าย (voicing effect) ซึ่งผลิตโดยผู้พูดชาวไทย 2) ศึกษาอิทธิพลของสระเกร็ง (tense vowel) และ สระคลาย (lax vowel) ว่ามีผลต่อการผลิตค่าระยะเวลาของสระที่นำหน้าเสียงก้อง และ ไม่ก้องของพยัญชนะท้ายในภาษาอังกฤษซึ่งผลิตโดยผู้พูดชาวไทยหรือไม่ อย่างไร ผู้ร่วมวิจัยประกอบด้วย นิสิตจากจุฬาลงกรณ์มหาวิทยาลัยจำนวน 10 คน จากคณะต่างๆ โดยผู้วิจัยได้ควบคุมความสามารถทางด้านภาษาอังกฤษของผู้เข้าร่วมวิจัยให้อยู่ในระดับเดียวกัน เครื่องมือที่ใช้ในการเก็บรวบรวมข้อมูลคือ การอ่านออกเสียงคำศัพท์ภาษาอังกฤษซึ่งเป็นคำเดียว ค่าระยะเวลาสระถูกวัดโดยใช้โปรแกรม Praat และ คำนวณด้วยสถิติพรรณนา (Descriptive statistics) ผลการวิจัยพบว่าผู้พูดชาวไทยผลิตค่าระยะเวลาสระซึ่งอยู่หน้าเสียงก้องและไม่ก้องของพยัญชนะท้ายไม่สม่ำเสมอ กล่าวคือ ผู้พูดชาวไทยผลิตความต่างของค่าระยะเวลาสระเมื่อนำหน้าเสียงก้องและไม่ก้องของพยัญชนะในบางครั้งเท่านั้น ผลการวิจัยยังแสดงให้เห็นถึงผลลัพธ์ที่ค่าระยะเวลาสระนำหน้าเสียงไม่ก้องยาวกว่าพยัญชนะเสียงก้อง ซึ่งผู้วิจัยให้นิยามปรากฏการณ์นี้ว่า อิทธิพลค่าระยะเวลาของสระตามความก้องของพยัญชนะท้ายแบบสวนทาง (countervailing effect)



สาขาวิชา ภาษาอังกฤษเป็นภาษานานาชาติ
ปีการศึกษา 2565

ลายมือชื่อนิสิต
ลายมือชื่อ อ.ที่ปรึกษาหลัก

6388001420 : MAJOR ENGLISH AS AN INTERNATIONAL LANGUAGE

KEYWORD voicing effect vowel duration L1 Thai speakers acoustic phonetics
D:

Chalita Taothong : The acoustic measurement of English vowel duration regarding final consonant voicing produced by L1 Thai speakers . Advisor: Asst. Prof. SUJINAT JITWIRIYANONT, Ph.D.

This acoustic study focuses on the phonetic phenomenon in English called the voicing effect in which vowel duration followed by voiced consonants is longer than those followed by voiceless consonant counterparts. This study aims to 1) study the duration of English vowels preceding voiced consonants longer than vowels preceding voiceless consonants, which are produced by L1 Thai speakers. 2) investigate the influence of English tense and lax vowels on the vowel duration ratio regarding voiced and voiceless final consonants, which are produced by L1 Thai speakers. Participants include 10 students studying at Chulalongkorn University from various faculties. The research instruments consisted of a pronunciation task. The vowel duration values were measured by Praat and analyzed by descriptive statistics. The results showed that Thai speakers inconsistently used voicing effect. They also exhibited the unexpected results called countervoicing effect which is when the vowel duration preceding voiceless consonants tends to be longer than the vowel duration preceding voiced consonants. It was found that most of the vowels which yield countervoicing effect were lax vowels. Thai speakers must be explicitly instructed in order to acquire the use of voicing effect.



Field of Study:	English as an International Language	Student's Signature
Academic Year:	2022
		Advisor's Signature
	

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Chalita Taothong

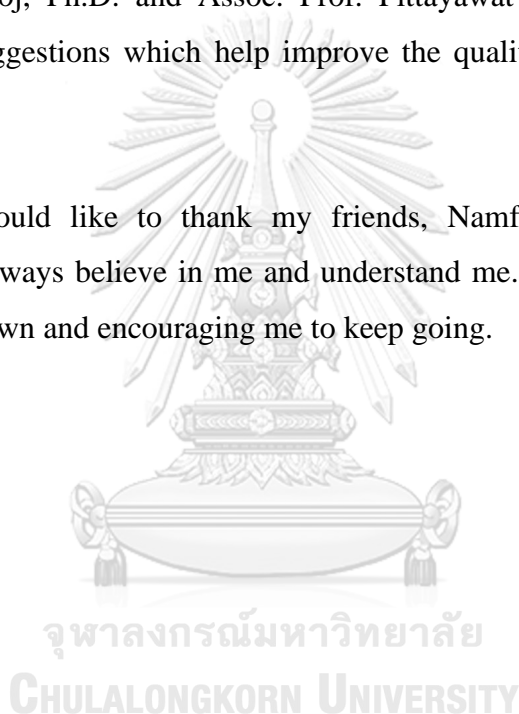


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1. Introduction

1.1 Background of the study

Although a native-like accent is not the goal of studying English as a lingua franca because even a strong foreign accent can be fully intelligible, some L2 learners of English still strive for an English native-like accent. A number of studies investigated the deviation of segmental features of L1 Thai speakers and most of them are related to consonantal problems (Chunsuvimol & Ronnakiat, 2001; Kitikanan, 2016; Roengpitya, 2011; Sahatsathatsana, 2017). Studies related to English vowels produced by Thai speakers, especially at the subphonemic level are scarce. The goal of the current study is to investigate the production of vowels by Thai speakers focusing on vowel duration specifically at the subphonemic level as a cue to final consonant voicing. This phenomenon is called voicing effect. Voicing effect is when a vowel preceding a voiced consonant tends to have a longer duration than a vowel preceding a voiceless consonant (House & Fairbanks, 1953; Mitleb, 1982).

One of the various factors which can influence vowel duration production is L1's vowel inventory and consonant inventory. Tsukada (2009) explored the tense and lax vowels produced by L1 Thai speakers. The result showed that Thai could also use duration as a cue of tense and lax vowels in English but to a greater extent than did the Australian English native speakers. However, some studies revealed different results. Although Chinese does not have phonemic vowel length, they were still able to use temporal feature to clearly distinguish tense and lax vowels as reported in Wang and Van Heuven (2006).

It is controversial whether voicing effect on vowel duration is universal. Ko (as cited in Yoneyama & Kitahara, 2014) mentioned that the voicing effect is based on universal articulatory mechanisms. House (as cited in Yoneyama & Kitahara, 2014) claimed that vowel durations in English are affected by both universal and language-specific characteristics of the postvocalic consonants and the target vowels themselves. Keating (1985) gave an opposing view. She argued that voicing effect is not universal but a phonologically conditioned pattern.

Several linguists have studied the voicing effect on vowel duration in English by L2 learners (e.g., Al-Deen, 2018 studied Arabic; Flege, 1993 studied Taiwanese and Mandarin; Shin, 2019 studied Korean; Skarnitzl & Šturm, 2016 studied Czech). The results from these studies were inconsistent, Flege (1993), for example, found that Taiwanese speakers whose L1 allows final consonants /p t k m n ŋ/ (Yang & Zhu, 2010) and has contrastive vowel length could significantly use voicing effect in English. Mandarin speakers whose L1 does not have contrastive vowel length and allows only nasal final consonant could also use voicing effect but with smaller extent than the Taiwanese group. Skarnitzl and Šturm (2016) found that Czech speakers whose L1 has vowel length contrast and final consonants are all voiceless could not significantly use voicing effect in English. To the best of my knowledge, there is no study exploring the voicing effect produced by L1 Thai speakers. Similar to Czech, Thai has distinctive vowel length. Unlike English but similar to Taiwanese and Czech, all final obstruent consonants in Thai are voiceless (Tingsabadh & Abramson, 1999). Although Thai has some similar features to Taiwanese and Czech, Thai contains more monophthongs than Taiwanese and Czech. The bigger vowel inventory in Thai might yield interesting results which can explain the effect of L1 on the use of voicing effect in English. Although most of the previous research mentioned that contrastive vowel length in L1 facilitates the usage voicing effect in English, Thai speakers might not be able to use voicing effect in English. Therefore, the current study aims to investigate the vowel duration difference of two consonantal contexts, i.e., voiced and voiceless final consonants produced by native Thai speakers. The target stimuli contain both English tense and lax vowels.

1.2 Research questions

1. How do L1 Thai speakers produce English vowel duration preceding voiced and voiceless consonants?
2. How do English tense and lax vowels influence voicing effect produced by L1 Thai speakers?

1.3 Research objectives

1. To study L1 Thai speakers' duration of English vowel preceding voiced and voiceless final consonants.

2. To investigate the influence of English tense and lax vowels on the vowel duration ratio regarding voiced and voiceless final consonants, which are produced by L1 Thai speakers.

1.4 Hypothesis Statements

1. Thai speakers do not produce English vowel with duration difference between vowels preceding voiced and voiceless consonants.
2. Both tense and lax vowel minimal pairs produced by Thai speakers show the same ratio of vowel duration in the position preceding voiced and voiceless consonants.

1.5 Significance of the study

The results of this study will reveal how L1 vowels and consonants influence voicing effect produced by non-native English speakers. It can also help pronunciation instructors to know whether vowel duration as a cue to contrastive consonant voicing is worth being more focused on to improve English native-like accent.

1.6 Definitions of Terms

1. **Tense and lax vowels:** Tense and lax vowels are phonological distinction of vowels to solve the description of the vowels which can be described identically. For example, /i/ and /I/ can be described as “high, front, unrounded” vowels. Tense and lax vowels can be classified by spectral and temporal phonetic features. Tense vowels are produced with more tenseness and relatively longer duration than their lax vowel counterparts. Lax vowels are produced with less articulatory movements than tense vowels and they typically have shorter duration than their tense vowel counterparts (Yavaş, 2020)
2. **Voiced and voiceless consonants:** Voiced consonants are consonants sounds produced with the vibration of vocal folds. Voiceless consonants are consonant sounds which are produced by letting the air pass through the vocal

folds which are held apart so there is no vibration of vocal folds (Ladefoged & Disner, 2012).

3. **Voicing effect:** A phenomenon where the duration of vowels changed due to the following final consonant voicing, i.e., voiced and voiceless consonants. Vowels are relatively longer when they precede voiced consonants comparing to those preceding voiceless consonants (Chen, 1970).
4. **Countervoicing effect:** A phenomenon when vowels preceding voiceless consonants are longer than those preceding voiced consonants. This term was used in the current study to describe the tendency of vowel duration values that appear against the voicing effect phenomenon regardless of statistical significance. It should be noted that the term, “countervoicing effect” was first coined and used in this study.
5. **Subphonemic:** Subphonemic cues are not themselves phonemic because they would not change the meaning of a word. They are critical for speech recognition because they provide a cue to the phonemic status of a sound; for example, vowel duration is a subphonemic cue to the final consonant voicing (Fergus, 2021).

2. Literature review

2.1 English and Thai segments

2.1.1 English and Thai consonants

Places of Articulation Manners of Articulation	Bilabial	Labio- dental	Dental	Alveolar	Post- Alveolar	Palatal	Velar	Glottal
Plosive	p b			t d			k g	
Affricate					tʃ dʒ			
Nasal	m			n			ŋ	
Fricative		f v	θ ð	s z	ʃ ʒ			h
Approximant				ɹ		j	w	
Lateral				l				

*Table 1: Consonant phonemes in English
(Highlighted phonemes are allowed in coda position)*

According to Table1, English has 24 consonant phonemes (i.e., /p b t d k g tʃ dʒ θ ð f v s z ʃ h ʒ w l ɹ j m n ŋ). 22 consonants, i.e., /p b t d k g m n f v θ ð s z ʃ h tʃ dʒ l w ɹ j/ can occur in the initial position while 21 consonants can occur in the final position (i.e., /p b t d k g m n ŋ f v θ ð s z ʃ tʃ dʒ l ɹ j/). Both voiced and voiceless consonants are allowed in the final position of the syllable (Carr, 2013).

Places of Articulation Manners of Articulation	Bilabial	Labio- dental	Dental	Alveolar	Post- Alveolar	Palatal	Velar	Glottal
Plosive	p p ^h b			t t ^h d			k k ^h	ʔ
Affricate					tʃ tʃ ^h			
Nasal	m			n			ŋ	
Fricative		f		s				h
Trill				r				
Approximant						j	w	
Lateral				l				

*Table 2: Consonant phonemes in Thai
(Highlighted phonemes are allowed in coda position)*

According to Table 2, Thai has 21 consonant phonemes (i.e., /p p^h t t^h d k k^h ʔ m n ŋ f s h tʃ tʃ^h r j w l h/. All consonants can occur in initial position of the syllable. Only /p t k m n ŋ w j ʔ/ are allowed in the final position of the syllable. /p t k/ are pronounced without audible release [p[̚]], [t[̚]], and [k[̚]] (Tingsabadh & Abramson, 1999; Vittrant & Watkins, 2019). Thai does not allow voiced obstruents in the final position of the syllable. It should be predicted that Thai will have a problem with the usage of voicing effect in English due to the absence of voiced obstruent codas.

2.1.2 English and Thai monophthongs

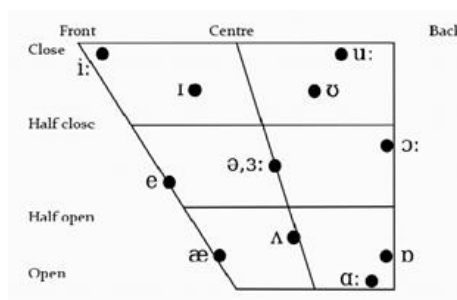


Figure 1: English tense and lax vowels

English has 12 monophthongs which can be divided into five tense vowels (i.e., /i ɜ ʌ ʊ u/) and seven lax vowels (i.e., /ɪ ɛ æ ʌ ɐ ʊ ə/). The last lax vowel /ə/ occurs in unstressed syllables only. Tense vowels have a higher tongue position and greater duration than their lax vowel counterparts. Tense vowels require stronger muscular tension for production (Yavaş, 2020). Unlike Thai vowels, English vowels are distinguished by vowel quality (i.e., their height, backness, lip position, and tenseness/ATR) and quantity (perceived length) (Colantoni, Steele, & Escudero, 2015). In English, vowel quality is the primary feature and quantity is a secondary feature for the categorization of vowel contrast (Bohn as cited in Avello, 2013).

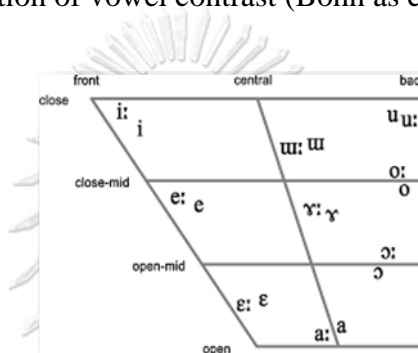


Figure 2: Thai tense and lax vowels

Thai has 18 monophthongs. They are 9 pairs of vowels with length contrast (i.e., short and long). Short vowels are /ɪ ɛ æ ʊ ɤ a u o ɔ/. Long vowels are /i: e: æ: u: ɤ: a: u: o: ɔ:/. Vowel length is a key to distinguishing vowel phonemes (Ladefoged & Disner, 2012; Tingsabadh & Abramson, 1999; Vittrant & Watkins, 2019). Although small tongue position differences between short and long counterparts are psychoacoustically detectable, the differences are too subtle to place with confidence in the vowel space (Tingsabadh & Abramson, 1993).

2.2 Voicing effect in different languages

Vowel duration can be influenced by the following consonants. It is known that vowel duration is longer when followed by voiced consonants than when it is followed by voiceless consonants. Various studies have investigated vowel lengthening caused by final consonant voicing (Hassan, 1981).

Chen (1970) studied voicing effect in different languages which are English, French, Russian, and Korean. The relative vowel duration values preceding voiced consonants to those preceding voiceless consonants of the target languages were 1.63 (English), 1.15 (French), 1.22 (Russian), and 1.31 (Korean). All target languages have voicing effect. Chen (1970) postulated that voicing effect is the universal phenomenon but the extent of vowel lengthening is a language-specific phonological structure. It should be noticed that voicing effect in English exaggerates the degree of vowel lengthening (Cho, 2015). Researchers reported the relative vowel duration values preceding voiced consonants to voiceless consonant in English as follow, 1.4 (Munro, 1993), 1.54 (Bent et al., 2008), 1.63 (Chen, 1970).

The claim of voicing effect as a universal phenomenon has been challenged. Mitleb (1984) examined the voicing effect in Jordanian Arabic. It was found that voicing effect does not exist in Jordanian Arabic. Keating (1979) studied the voicing effect in Polish. Polish has a rule of word-final devoicing. The vowel duration difference caused by final consonant voicing can be studied in the medial position only. The results showed that the mean ratio is 1.0 which indicated that Polish vowel duration does not change systematically due to the final consonant voicing. It indicates that voicing effect is not a universal phenomenon

2.3 Previous studies on voicing effect in English produced by L2 learners

Many studies have investigated voicing effect in English produced by L2 learners. The focus is on the correlation between participants' L1 phonology and the ability to use voicing effect. The results from the below studies are still varied and inconclusive.

Research Studies	L1 of participants	Results	Summary
Munro (1993)	Arabic	The Arabic speakers could significantly lengthen vowels before /d/ than before /t/ but the degree of vowel lengthening is still much smaller than English speakers.	Contrastive vowel length and consonantal voicing can lead to the ability to use voicing effect in English
Al-Deen (2018)	Arabic (Syrian) - contrastive vowel duration	Syrian EFL learners can use temporal feature as a	Contrastive vowel length and

	- contrastive final consonant voicing	cue of contrastive final consonant voicing in English.	consonantal voicing can lead to the ability to use voicing effect in English
Bent et al. (2008)	Chinese <ul style="list-style-type: none"> - No contrastive vowel duration - Fewer number final of consonants than English 	L1 Chinese speakers could significantly use voicing effect. The vowel duration difference between voiced and voiceless consonantal contexts is less than native English speakers.	Regardless of having few numbers of final consonants and an absence of contrastive vowel length, Chinese speakers were still able to use voicing effect
Crowther and Mann (1992)	Mandarin <ul style="list-style-type: none"> - No contrastive vowel duration - Fewer number final of consonants than English Japanese <ul style="list-style-type: none"> - Contrastive vowel duration - Fewer number final of consonants than English 	Both Mandarin and Japanese speakers could use voicing effect in English. Japanese produced vowel duration difference between two final consonant voicing contexts with greater duration than L1 Mandarin speakers	Lack of final stop consonants might not be the case for the difference between Japanese and Mandarin groups. Contrastive vowel length in L1 Japanese facilitates the use of English voicing effect
Flege (1993)	Mandarin <ul style="list-style-type: none"> - No contrastive vowel duration - Fewer number final of consonants than English Taiwanese <ul style="list-style-type: none"> - Contrastive vowel length - Final obstruents /p t k/ 	There was no significantly different production of adult Taiwanese and Mandarin speakers. Taiwanese could use voicing effect for every minimal pair but there was one minimal pair in which Chinese could not exhibit significant vowel duration difference.	Contrastive vowel length in L1 may lead to better performance on English voicing effect.
Chang (2008)	Japanese <ul style="list-style-type: none"> - Contrastive vowel length Korean <ul style="list-style-type: none"> - No contrastive vowel length 	Both participant groups exhibited significant voicing effect in English. Japanese produced greater vowel duration difference between two final consonant voicing contexts than L1 Korean speakers.	The phonological vowel length in Japanese facilitates the use of voicing effect in English.
Shin (2019)	Korean-English bilingual speakers who have lived abroad for more than ten years Korean EFL learners	Both speakers group significantly produced voicing effect in English. Korean-English bilingual	The length of exposure to the target language leads to native-like

		produced voicing effect with vowel duration difference similar to native English speakers.	pronunciation.
		Korean EFL learners produced vowel duration difference regarding final consonant voicing less than Korean-English speakers and native English speakers.	
Swain and Lee (2018)	Spanish speakers who have lived in the U.S. for 2.25 years on average <ul style="list-style-type: none"> - No contrastive vowel duration - Voiced obstruents are not allowed in the final position of the syllable. 	Spanish speakers could significantly produce voicing effect in English The degree of vowel lengthening was lesser than native English speakers.	Regardless of voiced final consonant and voiced final consonant, Spanish speakers could still produce voicing effect in English.

Table 3: Previous studies presenting the results of the significant use of voicing effect in English by EFL learners having different L1s

According to Table 3, regardless of contrastive vowel length, few numbers of final consonants, and the absence of voiced final obstruents, EFL learners still could significantly produce voicing effect in English. It seems like having contrastive vowel length will help EFL learners to produce voicing effect with greater vowel duration difference than EFL learners whose L1 do not have contrastive vowel length (Chang, 2008; Crowther & Mann, 1992; Flege, 1993). The length of living in English speaking countries could improve the use of voicing effect to be similar to native English speakers (Shin, 2019). More detailed for above mentioned studies in Table 3 can be found below.

Munro (1993) compared English vowel production of native Arabic speakers from several dialects to native English speakers' production. The participants were asked to pronounce words in 2 contexts, bvt and bvd (Initial consonant b + vowel + voiceless consonant t/ voiced consonant d). The results revealed that native Arabic speakers could significantly lengthen vowels before /d/ than before /t/ but the degree of vowel lengthening was still much smaller than English speakers.

Al-Deen (2018) investigated voicing effect in English produced by Syrian EFL learners whose L1 is Arabic. Arabic has contrastive vowel duration and contrastive final consonant voicing. (Al-Deen, 2018) also provided a literature review on the existence of voicing effect in Arabic but the results were not consistent. The results revealed that Syrian EFL learners can use temporal feature as a cue of contrastive final consonant voicing in English.

Crowther and Mann (1992) examined the temporal cue of final consonant voicing in English produced by native speakers of English, Mandarin, and Japanese. The extent of vowel lengthening by the three participant groups was compared to determine the effect of native languages. According to Flege and Wang (as cited in Crowther & Mann, 1992), if a speaker's L1 does not allow final stop consonants or contains few final consonants, it would be difficult for him/her to use the vocalic cues to final consonant voicing in English. Mandarin and Japanese both have the fewer number of final consonants than English. The difference between these two languages was that Japanese has phonemic vowel length while Mandarin does not. The result showed that the average vocalic duration contrasts were 75.9, 25.5, and 12.8 ms for English, Japanese, and Mandarin speakers, respectively. The extent of vocalic cues produced by Mandarin was less than that by Japanese speakers. This indicated that the lack of final stop consonants might not be the case for the difference between Japanese and Mandarin groups. This may attribute to the reason that Japanese speakers applied long and short vowels in their L1 to the vocalic cues of final consonant voicing in English.

Flege (1993) investigated the production and perception of vowel duration preceding English final /t/ and /d/ of Chinese subjects. The subjects were L1 Taiwanese and Mandarin speakers. Taiwanese has final obstruents /p t k/ but not /b d g/ while Mandarin has only two final consonants, /n/ and /ŋ/. Taiwanese also has a contrastive vowel length. The results showed that adult Taiwanese and Mandarin speakers produced smaller vowel duration differences when compared to English native speakers. There was no significantly different production of adult Taiwanese and Mandarin speakers. However, it was found that within seven tested minimal pairs, Taiwanese could use voicing effect for every minimal pair but there was one minimal

pair in which Chinese could not exhibit significant vowel duration difference. This may imply that the contrastive vowel length could facilitate the use of voicing effect in English.

Bent et al. (2008) investigated the vowel length before voiced versus voiceless obstruents. The participants were native Chinese and English speakers. The English proficiency of Chinese speakers was sufficient to enter the graduate program at Northwestern University. Unlike English, Chinese does not have contrastive vowel length and only nasal consonants are allowed in the final position of the syllable. They were asked to read sentences containing target words. The results showed that the Chinese speakers can use temporal feature to distinguish voicing of final consonants in English; however, the relative value of vowel duration preceding voiced consonants to those preceding voiceless consonants was less than native English speakers (1.17 for Chinese speakers and 1.54 for English speakers).

Chang (2008) examined the production of vowel durational cue of English final consonant voicing by native Japanese, Korean, and English speakers. This study aimed to investigate how L1 phonology plays a role in using vowel duration as a cue for final consonant voicing. The reason why Japanese and Korean speakers were chosen was that these two languages have different phonological status of vowel length. In Japanese, vowel length is phonemic. In Korean, there is no vowel length distinction. The participants were asked to read sentences with the target words embedded at the end of each sentence. The results revealed that all the three groups of speakers could significantly use vowel duration as a cue of contrastive final consonant voicing. It should be noted that the effect of vowel lengthening before voiced consonants produced by the Korean speakers was less than the other two speaker groups. The Japanese speakers produced a stronger degree of vowel lengthening than the Korean speakers. However, the degree of vowel lengthening by Japanese was still less than the native English speakers. The results suggested that the phonological vowel length in Japanese was expected to facilitate the use of voicing effect in English.

Shin (2019) studied the production of voicing effect of three speaker groups, i.e., English native speakers, Korean-English bilingual speakers who have lived

abroad for more than ten years, and Korean EFL learners. Although Korean has voiced consonants, they occur as allophones in the intervocalic position only. The stimuli were words with final sibilant consonants in a carrier sentence, ‘Say “_____” again’. The results showed that all the three participant groups could significantly lengthen vowel duration preceding voiced consonants. However, a difference between groups was found. The Korean-English bilingual group and the native speaker group produced a similar degree of voicing effect while the Korean EFL learners produced less voicing effect than the other two groups. This indicates that the voicing effect can be acquired by learning. It also shows that the length of exposure to the target language leads to native-like pronunciation.

Swain and Lee (2018) explored the vowel duration followed by distinctive final consonant voicing produced by native English speakers and native Spanish speakers who have lived in the U.S. for 2.25 years on average. In this study, the participants were asked to read words containing six stop consonants in English (/b p d t g k/) in a carrier sentence. Spanish has consonant voicing distinction but all Spanish voiced consonants are not allowed at the final position of the syllable. There are only five vowels in Spanish and there is no vowel length distinction. It was found that Spanish speakers could significantly produce vowel duration difference between voiced and voiceless stops. It should be noted that the degree of vowel lengthening was lesser than native English speakers.

Research Studies	L1 of participants	Results	Summary
Skarnitzl and Šturm (2016)	Czech <ul style="list-style-type: none"> - Contrastive vowel length - Voiced obstruents are not allowed in the final position of the syllable. 	Czech speakers did not exhibit significant vowel lengthening before voiced consonants.	Having contrastive vowel length in L1 does not facilitate the use of voicing effect in English. The absence of final consonant in L1 may cause the inability to use voicing effect in English.
Rasskazova et al. (2016)	German <ul style="list-style-type: none"> - syllable-final obstruent devoicing rule 	German speakers could not significantly used vowel duration difference as a cue to	The absence of final consonant in L1 may cause the inability to use voicing effect in

final consonant voicing.	English.
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Table 4: Previous studies presenting the results of the insignificant use of voicing effect in English by EFL learners having different L1s

Table 4 shows previous studies with insignificant voicing effect produced by EFL learner results. It was found that contrastive vowel length in L1 did not facilitate the use of voicing effect in English. Additionally, the absence of voiced obstruents in the final position of the syllable may lead to the inability to use voicing effect in English. More details on previous studies presented in Table 4 can be found below.

Skarnitzl and Šturm (2016) studied the voicing effect produced by Czech EFL learners. The voiced consonants are neutralized as voiceless consonants word-finally. Czech has distinctive vowel duration. Based on Crowther and Mann (1992), it should be predicted that Czech would be able to use temporal feature to distinguish final consonant voicing in English. They were asked to read target words embedded in the same sentence. It was found that the Czech speakers did not exhibit significant vowel lengthening before voiced consonants. This might be because Czech speakers also pronounce voiced final consonants in English as voiceless consonants. Therefore, the minimal pairs with different final consonant voicing were produced identically. The findings were contrary to Crowther and Mann (1992) and Chang (2008).

Rasskazova et al. (2016) investigated the final consonant voicing contrast by native German speakers. German is different from English because German has syllable-final obstruent devoicing rule. The German speakers were asked to read the target words, beat/bead, bit/bead, seat/seed, and sit/sid. The stimuli contain tense vowel /i/ and lax vowel /ɪ/ in order to study the interaction of tense and voicing effect. The results showed that the German speakers could not significantly use vowel duration difference as a cue to final consonant voicing.

To conclude, some features of vowels and consonants in L1 might be the factor facilitating the use of voicing effect in English by L2 learners, for example, the distinctive vowel length in L1. Three previous studies seem to show an agreement that speakers whose L1s have vowel length distinction could produce the stronger degree

of voicing effect than those whose L1s do not have vowel length distinction (Chang, 2008; Crowther & Mann, 1992; Flege, 1993). Contrarily, the results from Skarnitzl and Šturm (2016) showed that Czech could not significantly use voicing effect although Czech has contrastive vowel length. Regardless of vowel length distinction in L1, Chinese (Bent et al., 2008), Korean (Chang, 2008; Shin, 2019) and Spanish speakers (Swain & Lee, 2018) were able to significantly produce voicing effect in English.

3. Methodology

3.1 Research Design

This acoustic study focuses on the phonetic phenomenon in English called the voicing effect in which vowel duration followed by voiced consonants is longer than those followed by voiceless consonant counterparts. This quantitative study aims to investigate the voicing effect produced by Thai speakers. The vowel duration measured in real time was in milliseconds. The mean duration values and ratios of vowels preceding voiced consonants to those preceding voiceless consonants were calculated. Due to the unexpected results named “countervoicing effect”, the inferential statistic cannot be used for finding the significance of vowel duration difference based on the voicing effect phenomenon. The inferential statistic cannot indicate whether vowel duration difference between voiced and voiceless consonant contexts is significant or non-significant in what directions, i.e., voicing effect or countervoicing effect.

3.2 Participants

The participants were 10 students from Chulalongkorn University studying in various faculties (i.e., the Faculty of Education, the Faculty of Psychology, the Faculty of Allied Health Sciences, and the Faculty of Communication Art). The participant’s requirement is that they do not study in the Faculty of Arts or the international program from other faculties. This is because students from the Faculty of Arts and the international program tend to have more chances to expose to English. To control the English proficiency of the participants, the participants must have CU-

TEP score ranging from 45-68 points (middle intermediate to intermediate English proficiency). The other participants' requirement is that they have never studied or stayed in countries that use English as an official language. They have never joined an English pronunciation course or courses related to English phonetics and phonology.

3.3 Stimuli

The stimuli consist of 6 minimal pairs (12 words) with CVC syllable structure. All words are monosyllabic except the word 'pudding'. This is because of the limitation of finding a monosyllabic minimal pair for 'put'. Within these 6 minimal pairs, 3 pairs contain lax vowels, i.e., /ɪ, ɛ, ʊ/ and the other 3 pairs contain tense vowels, i.e., /i, ɑ, u/. The vowel /e/ was not used because /e/ in English is diphthongized. This study specifically investigates monophthong. The onsets are different in each word to accommodate the occurrence of the target vowels. According to Laeufer (1992) the manner of articulation can affect the degree of voicing effect. Therefore, the manner of articulation of the final consonants is controlled. The place of articulation of final consonants was also controlled as it can affect vowel duration (Crystal & House, 1988) In this study, the final consonants are voiceless and voiced alveolar stops which are /t/ and /d/, respectively, to investigate how contrastive final consonant voicing influences preceding vowel duration. There are 5 sets of stimuli containing the same 12 words but with different random order. The stimuli are presented in Table 5.

Lax vowels		Tense vowels	
voiceless final consonants	voiced final consonants	voiceless final consonants	voiced final consonants
hit /hɪt/	hid /hɪd/	beat /bit/	bead /bid/
fet /fɛt/	fed /fɛd/	got /gat/	god /gad/
put /pʊt/	pudding /pʊdɪŋ/	moot /mut/	mood /mud/

Table 5: Stimuli contain tense and lax vowels and final consonants /t/ and /d/ which have different consonant voicing

3.4 Data Collection

The data were collected online. The participants were asked to record their speech by themselves using Audacity audio recording software on their own laptops or PCs and headphones with a microphone. The voice was recorded with normal speaking rate in a quiet room. The participants were asked to hold the microphone approximately 10 cm from their mouth. The participants ensured that their fingers would not cover the microphone. The sampling rate was set at 44100 Hz. To control the recording, the participants were instructed by the researcher via zoom. Each word was presented 5 times in random order on a computer screen via zoom. The participants were asked to pronounce every word they saw on the computer screen. Prior to the real data collection, the participants got a chance to try pronouncing words which were not used in the data analysis. This is to let participants get used to the process of recording and also to check the recording quality. After finishing recording, the participants sent the recording file in .wav format to the researcher's google drive.

3.5 Data Analysis

The best three tokens of each target word pronounced by each participant (12 words x 3 repetitions x 10 participants = 360 tokens) were chosen for vowel duration measurement. In this study, Praat speech software was used for vowel measurement. The spectrogram was mainly used for vowel duration indication and was also accompanied by waveform (Yi, 2017). Vowel onset was identified by the beginning of the grey horizontal bar for vowels. The vowel offset was identified by the absence of full formant structure as can be seen in Figure 3 (Machač & Skarnitzl, 2013).

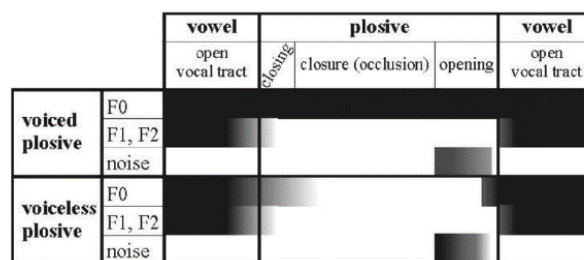


Figure 3: Vowel offset indication in the plosive context

To compare the degree of vowel duration difference between the two consonantal contexts, i.e., voiced and voiceless final consonants, ratios of vowel duration values preceding voiced consonants to those preceding voiceless consonants were calculated. If the ratio of vowel duration between two consonantal contexts is 1, it means the difference in vowel durations between two consonantal contexts cannot be found. If the ratio is above 1, it means the voicing effect exists but it does not mean that the voicing effect is statistically significant. The higher the ratio, the higher the degree of vowel duration difference. In case the ratio is less than 1, there is a difference in vowel duration between 2 consonantal contexts but it is a countervoicing effect.

Inferential statistics cannot be used to investigate the significance of voicing effect produced by native Thai speakers. This is because there are some minimal pairs showing the countervoicing effect. If these pairs are used in the statistical analysis, it will deviate the results. The researcher used only descriptive statistics to analyze the degree of vowel duration difference and the tendency toward voicing effect of vowel duration of participants individually and holistically.

4. Results

1. How do L1 Thai speakers produce English vowel duration preceding voiced and voiceless consonants?

Participants	Vowels					
	i	ε	a	ɪ	u	ʊ
1	*0.933	1.232	1.032	*0.967	1.028	*0.522
2	1.094	1.139	1.063	*0.960	1.183	*0.480
3	*0.758	1.184	1.201	*0.873	1.044	*0.623
4	1.159	*0.942	1.202	1.014	1.278	*0.677
5	1.091	1.113	1.748	1.162	1.132	*0.438
6	1.116	1.060	1.858	*0.958	1.119	1.114
7	*0.940	1.171	1.356	1.069	1.015	*0.885
8	1.109	1.128	2.905	*0.934	1.058	*0.812
9	1.238	*0.976	2.676	1.013	2.037	*0.703
10	1.046	1.475	1.011	1.006	1.212	*0.589

*Table 6: Vowel duration ratios of vowel preceding a voiced consonant to vowels preceding a voiceless consonant
(The ratios with asterisk mean countervoicing effect)*

Table 6 shows the ratios of vowel duration preceding voiced to those preceding voiceless consonants of all participants. It was found that Thai speakers inconsistently produced vowel duration ratio regarding final consonant voicing. Some minimal pairs were produced with vowel preceding voiced consonant longer than vowels preceding voiceless consonants. For example, Participant 1 produced /ε a u/ with a tendency toward voicing effect with vowel duration ratios above 1. The vowels /i ɪ ʊ/ were produced against voicing effect which the researcher called “countervoicing effect”. It should be noted that vowel duration difference values regarding final consonant voicing in this study were not calculated to show the statistical significance. Based on the vowel duration ratios, vowel duration between voiced and voiceless consonant exhibited duration difference with a small degree, e.g., 1.028 which is the ratio of /u/ minimal pair by Participant 1. This means /u/ preceding /d/ is 2% longer than /u/ preceding /t/. The ratio 0.933 which was derived from /i/ minimal pair by Participant 1 means /i/ preceding /d/ was 7% shorter than /i/ preceding /t/. The participants produced countervoicing effect the most when they pronounced /ʊ/ minimal pair. Considering the production of /ɪ/ by Participant 10, the vowel duration ratio was 1.006, indicating that there was no vowel duration difference between two final consonant contexts. The raw vowel duration values (in ms) of /hid/ and /hit/ minimal pair of Participant 10 were both 0.115 and 0.115. The vowel /u/ and /a/ were the only two vowels which were produced by every participant with the tendency towards voicing effect. In conclusion, L1 Thai speakers did not use vowel duration as a cue for final consonant voicing as can be seen from the inconsistent pattern of vowel duration.

2. How do English tense and lax vowels influence voicing effect produced by L1 Thai speakers?

Participants	i	ɛ	ɪ	ʊ
1	/		/	/
2			/	/
3	/		/	/
4		/		/
5				/
6			/	
7	/			/
8			/	/
9		/		/
10				/
	3	2	5	9

Table 7: Frequency of vowel exhibiting countervoicing effect

Participants	i + vl	i + vd	ɛ + vl	ɛ + vd	ɪ + vl	ɪ + vd	ʊ + vl	ʊ + vd
1	0.250	0.233			0.080	0.077	0.092	0.048
2					0.109	0.105	0.091	0.044
3	0.135	0.102			0.102	0.089	0.111	0.069
4			0.104	0.098			0.077	0.052
5							0.152	0.067
6					0.095	0.091		
7	0.235	0.221					0.136	0.121
8					0.090	0.084	0.090	0.073
9			0.127	0.127			0.107	0.075
10							0.124	0.073

Table 8: Raw vowel duration in millisecond of vowels exhibiting countervoicing effect by each participant

Table 7 shows the frequency of vowels which have countervoicing effect (vowel duration ratio less than 1) produced by each participant. It was found that vowels exhibiting countervoicing effect were /i ɪ ʊ ɛ/. Among vowels exhibiting countervoicing effect, /i/ is the only tense vowel and the rest are lax vowels. This indicated that lax vowels led to the production of vowel duration preceding voiced consonants shorter than vowel preceding voiceless consonants. The vowel /ʊ/ was produced with the most frequency of countervoicing effect, i.e., nine out of ten

participants produced /ʊ/ with countervoicing effect. Only Participant 4 and 9 produced /ɛ/ with the tendency to countervoicing effect. For clarity, the raw vowel duration values in millisecond were provided in Table 8. All vowel duration values preceding voiced consonant were shorter than vowel duration values preceding voiceless consonants, for example, the duration values of /ʊ/ produced by participant 9 were 0.107 before a voiceless consonant and 0.075 before a voiced consonant.

5. Discussion and Conclusion

5.1 Discussion and conclusion

This study investigated the English vowel duration preceding voiced and voiceless consonants produced by L1 Thai learners. The results suggested that Thai speakers did not consistently use vowel duration difference between two final consonant contexts. The absence of the voicing effect of Thai speakers is possibly due to the inexistence of final voiced obstruents in L1 Thai. In Thai, there is no perceptually motivated reason to lengthen the vowel. On the other hand, English used different vowel duration for auditory reason (Kluender et al., 1988). A long vowel should make a short closure interval of voiced consonants seem shorter and a long vowel should make a long closure of voiceless consonants seem even longer. Thai distinguishes vowel counterparts by duration. By comparing the duration of a lax vowel followed by a voiced consonant and a tense vowel followed by voiceless consonant by L1 Thai speakers, a lax vowel followed by voiced consonant was still shorter than a tense vowel followed by voiceless consonant. It might be that Thai speakers did not use voicing effect in order to preserve the distinction between vowel counterparts. This is against the findings of Chang (2008), who found that Japanese speakers could significantly use voicing effect due to the contrastive vowel length in L1 Japanese.

The unexpected result was found. It was the tendency of countervoicing effect on some vowel production. Most of the vowels which show countervoicing effect were lax vowels. The vowel /ʊ/ exhibited the most frequency of countervoicing effect. This can be contributed to the two syllables of the stimuli /pʊdding/ as mentioned by Klatt (1973) that voicing effect in polysyllabic words is much smaller than in

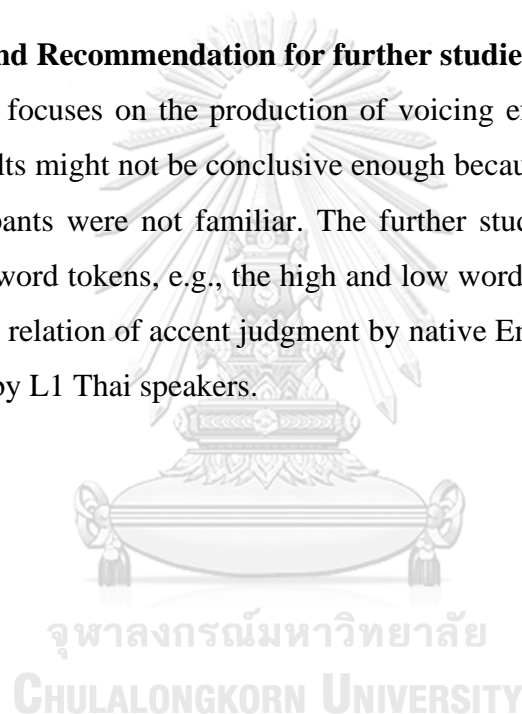
monosyllables. The minimal pair containing /ɪ/ were also produced with vowel duration preceding a voiceless consonant longer than a voiced consonant. This might be because of the hesitation of participants to pronounce the word “hid” /hɪd/. The participants spent more time than other words to pronounce /hɪd/ as they thought it can also be pronounced as /haɪd/. The hesitation also occurred with the word “bead” /bid/. The participants thought it might be pronounced as /bed/. The other reason why lax vowel showed countervoicing effect more than tense vowel is because lax vowel is more marked than tense vowels. Lax vowels tend to be more difficult to acquire than tense vowels (Maddieson & Disner, 1984). Although Thai has large vowel inventory, Thai does not have lax vowels. All Thai vowels are tense and distinctive by length (Zirivarnphicha et al., 2022). The big amount of vowel inventory does not facilitate Thai speakers to produce English lax vowels as native English speakers do. In the current study, when Thai speakers produce lax vowels, they produced them with more tendency to deviate from English phonetic realization. According to researcher’s observation, in terms of relation between voicing effect production and accent, it was found that Participant 5 and 6 have a good accent and they produced voicing effect for only one vowel which were /ʊ/ and /ɪ/ respectively. This might show the correlation of a good accent and use of vowel duration difference regarding final consonant voicing. In more details, Participant 5 and 6 produced voicing effect for all 3 repetitions of the target minimal pairs. The repetitions of the other minimal pairs did not show countervoicing effect. It should be noticed that Participant 1 exhibited countervoicing effect on three vowels although she has a good accent. Participant 1 also produced countervoicing effect inconsistently among the 3 repetitions of each minimal pair. To elaborate, Participant 1 exhibited vowels with ratio less than 1 for /ɪ/ minimal pair only for the first repetition (0.066 before /d/ and 0.083 before /t/). For the vowel /i/, it showed countervoicing effect only on the second and third repetitions by Participant 1. For the vowel /ʊ/, the countervoicing effect was found on all 3 repetitions. It was found that countervoicing effect by other participants generally occurred on the first repetition and then inconsistently occur on the second and third repetitions.

The overall results support the findings of Skarnitzl and Šturm (2016), who investigate the vowel duration preceding voiced and voiceless consonants in English

by L1 Czech speakers. They found that Czech speakers were not able to significantly produce voicing effect. Czech and Thai have similar phonology in that all final obstruents are voiceless and have contrastive vowel duration. However, in the study of Skarnitzl and Šturm (2016), they did not mention the countervoicing effect. When the Thai participants try to differentiate voiced and voiceless final consonants in English, some of them tried to make the difference on final consonant itself by exaggerating their pronunciation. This suggests that voicing effect is the linguistic element which has to be explicitly taught.

5.2 Limitations and Recommendation for further studies

This study focuses on the production of voicing effect by L1 Thai speakers. However, the results might not be conclusive enough because of the word tokens with which the participants were not familiar. The further studies should investigate the different types of word tokens, e.g., the high and low word frequency. Further studies could also find the relation of accent judgment by native English speakers and voicing effect production by L1 Thai speakers.



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