L2 English Fricative Production by Thai Learners

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September 2016

Abstract

In early research on L2 (second language) phonology, researchers mainly focussed on whether L2 learners can achieve ‘target-likeness’, which relates to whether or not a sound is perceived as the intended target or whether it fits into the expected IPA category as determined by trained phonetician(s). The popular model for this focus was the contrastive analysis hypothesis (CAH) (Lado, 1957). Later research extended the focus to judgements of ‘native-likeness’, which is the extent to which the speaker’s L2 sound production has native-like qualities. Methods such as accent rating tasks and acoustic measurements have become popular over time, together with investigations of how the results correlate with external factors which are thought to influence L2 speech learning. Well-known models such as the Speech Learning Model (SLM) (Flege, 1995) and the Perceptual Assimilation Model (PAM) (Best, 1995) have been very influential in this field, but are mainly based on assumptions regarding L2 learners in a naturalistic setting.

The aim of this thesis is to investigate L2 English fricative production by Thai learners of English with a combination of focus on target-likeness and native-likeness through four types of analysis: impressionistic, sound identification, accent rating, and acoustic analyses. This thesis also explores external factors which may contribute to target-likeness in L2 production which is more important than native-likeness as it helps in communication between interlocutors. The L2 fricatives are divided into those that have a counterpart in Thai (/f, s/ henceforth ‘shared’ sounds) and those that do not (/v, θ, ð, z, ʃ/, henceforth ‘non-shared’). As CAH focuses on target-likeness, it predicts that shared sounds are easy to produce; SLM, on the other hand, focuses on native-likeness and predicts that shared sounds are difficult to produce. Results from the four experiments in this study show mixed results.

In terms of results from impressionistic and sound identification analyses, CAH-based hypotheses accurately predict most results, which show that shared sounds are more frequently produced in a target-like manner and more accurately identified. In terms of results from the accent rating task, SLM had to be rejected in this case, as results showed that shared fricatives were more often produced in a native-like manner, unlike non-shared fricatives. In the acoustic investigation, differences in the realisations of L2 shared sounds supported SLM-based hypotheses in some contexts. And although SLM-based hypotheses were disconfirmed when it came to the accent rating of L2 shared and non-shared sounds, the phonetic properties of non-shared sounds in the realisations that were deemed target-like were native-like in many contexts, suggesting some L2 attainment for non-shared sounds. Taken as a whole, these results emphasise the need to focus on both target-likeness and native-likeness in investigating L2 speech production. They also imply that L1 and L2 sound comparison is context- and task-dependent.

Keywords: L2 production, L2 phonology, fricatives, Thai, English, sound identification task, accent rating task, acoustic investigation, crosslinguistic comparison

Acknowledgements

The present work is the culmination of my PhD. The knowledge I have gained from this thesis is interdisciplinary and includes statistics, acoustics and sound transcription. I would like to thank both of my supervisors – Ghada Khattab for her advice on theoretical issues and moral support and Jalal Al-Tamimi for his suggestions on Praat regarding acoustic analysis, sound identification and accent rating tasks. I also would like to thank Martha Young-Scholten and Sam Hellmuth for being my examiners and for giving me useful advice and relaxing but thought-provoking discussion during my viva. Without them, this thesis could not have been done. Special thanks also go to Gerry Docherty who gave me a chance to study on this IPhD programme and who was my phonetics lecturer. I have learnt many things from his knowledge and experience.

Regarding statistical analyses, many people have given me advice. The first person to thank is Jakris Eu-ahsunthornwattana who has given me advice on statistical theory. He explained everything well. The second person that I would like to thank is Ittichote Chuckpaiwong who was in Newcastle for a short time and who I met by chance at Leazes Park while he was running. He is the first person who introduced me to the R programming language. Even though we had never met before, he devoted his time to introducing this programme to me. I appreciated the unity of being Thai that connected us. The other two people I would like to thank are my colleagues – Katharina Nimz and Siti Syuhada Faizal who have also advised me on R programming. I also would like to give special thanks to statisticians on http://stats.stackexchange.com/ for their answers to my statistics questions, and to David Nithakorn for his help with language proof-reading.

I also have to thank my family (Preecha Kitikanan, Sumitra Kitikanan and Tharinee Kitikanan) who understood that the mission of the study was for the benefit of our home country and hence supported their daughter in doing it. I am sorry that I only went home twice during my study due to the stress of having to complete the work in limited time period and the high cost of travelling. My determination to study was restored when I called them after times of stress. Regardless what time it was in Thailand – with six to seven hours difference in the time zone between Thailand

and the UK, which was often close to their sleeping time – they were willing to answer my calls and consoled me. They were always my soft fluffy mattress.

Another source of moral support is from my close friend: Athicha Wiruhayan who has been a friend of mine since we were eight years old in primary school. Although we have usually been living in different countries, she made me feel that she was very close to me by writing me letters, emails and chatting online before the advent of Facebook. Our online communication was almost daily. She was a part of my routine to share both happy and sorrowful stories. Last but not least, I would like to dedicate this success to Naresuan University who supported me financially with a full scholarship for four years. Without this scholarship, I would not have had a chance to pursue my PhD in the UK.

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Chapter 1. Introduction

1.1 Area and topic

Research on the development of second language (L2) phonology started to gather a lot of interest around the 1960s when the discrepancy between the first language (L1) and L2 sound systems was considered the main cause of difficulty in L2 sound learning (Weinreich, 1953; Lado, 1957; Stockwell and Bowen, 1965). This discrepancy was thought to lead to transfer, a process in which L1 sound production patterns transferred to L2 sound learning in either positive or negative ways. The popular model at that time was the contrastive analysis hypothesis (CAH) by Lado (1957), which predicted errors from cross-phonological differences between the L1 and the L2. According to CAH, a difficulty in producing L2 sounds occurs due to the nonexistence of these sounds in the native sound system or in the same position of the syllable, because L2 learners cannot transfer their L1 sound to the L2 sound production. For example, Thai L2 learners find /z/ difficult to articulate as it does not occur in Thai (Kanokpermpoon, 2007). They also have difficulty producing /s/ in final position even though it is a Thai phoneme, as /s/ does not occur in final position in Thai (Brière and Chiachanpong, 1980; Charmikorn, 1988).

In terms of data analysis at that time, researchers commonly used broad phonetic transcription to investigate L2 sounds, which were generally judged as either ‘correct’ or ‘incorrect’ (e.g. Brière and Chiachanpong, 1980; Sheldon and Strange, 1982; Bada, 2001). The focus of these researchers was on whether the sound production was target-like, or whether the realisation of a sound was perceived as similar to the IPA symbol that represented it. For example, Brière and Chiachanpong (1980) predicted errors in American English /v/ by Thai learners based on CAH, assuming that it will be difficult to produce because it does not occur in the Thai sound system. Their results showed that CAH-based hypothesis correctly predicted main errors, as the majority of errors were due to /v/ being produced as [f], which shares the most features with /v/.

In the 1960s and 1970s, the notion of CAH enjoyed less widespread acceptance because it is based solely on differences between phonemic systems (James, 1980) and the difference in phonemic inventory is merely one aspect of cross-phonological differences; other aspects relating to the differences between phonological systems were emerging as worthy of investigation, such as the phonetic characteristics of sounds, examined using detailed phonetic transcription, acoustic measurement, or perceived degree of accentedness. The popularity of CAH also declined because it did not account for all errors made by L2 learners (Sridhar, 1980) and could not explain why some L2 learners fail to articulate more target-like sounds while others are successful in producing them. CAH did not take into account variability in speech realisations in production either (Dickerson, 1974), failing to take account for differences in the realisation of a target sound in different productions, such as when L2 English /v/ is realised as both [w] and [v].

In later focus of L2 phonology research (in the late 1970s), L2 phonology researchers extended the focus from target-likeness to native-likeness. The interest of native-likeness of L2 sounds has developed from sociolinguistic research regarding sound variants which depend on both linguistic - such as degree of stress - and nonlinguistic factors, such as age, ethnicity and social status (Flege, 1988). Researchers began to look at an increasing number of factors that may account for variability in L2 speech production, such as length of residence (e.g. Asher and García, 1969; Purcell and Suter, 1980; Flege *et al.*, 1995b; Drummond, 2010), L2 exposure (e.g. Purcell and Suter, 1980; Flege and Fletcher, 1992; Elliott, 1995) and gender of speakers (e.g. Jennische and Sedin, 2003; Farantouri *et al.*, 2008; Verhoeven and van Leeuwe, 2011; Vidor-Souza *et al.*, 2011).

As a result of this shift in focus, two models emerged which are still influential to this day. The first is the Speech Learning Model (SLM), which was devised by Flege (1995) to account for L2 development across the life span of L2 learners in a natural L2 setting. SLM aims to account for L2 speech perception through the link to production. SLM classifies an L2 sound that is represented by a similar IPA symbol to an L1 sound as ‘similar’ or ‘identical’ sound. These two terms are different in that phonetic qualities of similar sounds are different whereas those of identical sounds are similar. For an L2 sound that is represented by an IPA symbol that is not used in the L1 sound system, SLM terms this as a ‘new’ sound. A similar sound is deemed more difficult to learn than a new sound, as L2 learners are thought to equate it with the closest L1 sound – this phenomena is called ‘equivalence classification’ (Flege, 1987, p. 49). One main external factor of interest for SLM which is thought to influence the degree of success in L2 learning is age of arrival (AOA). According to SLM, the earlier L2 learners arrive in the L2 country, the higher L2 speech proficiency they will have (e.g. Flege *et al.*, 1996; Mackay *et al.*, 2006).

Another model which developed around the same time as SLM is the Perceptual Assimilation Model (PAM) (Best, 1995), which focuses on L2 speech perception by naïve listeners. The term ‘naïve’ here refers to learners who have little or no experience with sounds in the target language. According to PAM, these listeners will assimilate L2 sounds with sound(s) in their L1 to different degrees depending on how similar the L2 sounds are to their L1 counterparts. PAM was later extended to account for L2 learning in a natural setting, rather than naïve listeners. This new model was called ‘PAM-L2’ (Best and Tyler, 2007), and focussed on the role of factors other than perceptual difference and similarity of L1 and L2 sounds, e.g. word frequency, vocabulary size, amount of L2 exposure and input from native speakers of L2.

Unlike the impressionistic analyses using phonemic transcription that were carried out under CAH, researchers later focused on similarities and differences between L1 and L2 sounds as perceived by native speakers of the L2 (e.g., Bohn and Flege, 1992; Flege *et al.*, 1995a; Flege *et al.*, 1997). Besides focusing on target-likeness, the focus of research also expanded to native-likeness using accent rating tasks (Munro *et al.*, 1996; Flege *et al.*, 2003; Hayes-Harb *et al.*, 2008) and acoustic analysis (Bohn and Flege, 1992; Flege *et al.*, 1995a; Flege *et al.*, 2003; Escudero and Williams, 2011). The focus of target-likeness was on viewing the L2 sound in terms of ‘adequacy’ (Flege, 1988, p. 229), which relates to the success of the message received by the listener; native-likeness, on the other hand, relates to ‘authenticity’ (Flege, 1988, p. 230), which explores whether a native listener of the target language can tell that the L2 sound is produced by non-native speakers. The concept of L2 production judged by native speakers is called the ‘pronunciation norm’, which refers to ‘the collective judgment of native speakers concerning how a sound ought to be pronounced’ (Flege, 1988, p. 229). In this thesis, target-likeness refers to when the L2 sound production falls within the relevant IPA category, which is a rough measure of the degree of intelligibility of the L2 sound. Native-likeness, on the other hand, refers to when the L2 sound has native-like phonetic qualities or sounds native to native speakers of the target language.

The following thesis employs four main methods of analysis to probe into target-likeness and native-likeness in L2 production: 1) impressionistic analysis using phonemic transcription is used to identify broad categories of realisations of an L2 sound; 2) impressionistic analysis of the L2 sound using a group of native speakers: the aim is to investigate the degree of identification of an L2 sound based on the perception of L2 native speakers; [1] 3) accent rating: the aim is to explore the degree of accentedness of L2 production when judged by native speakers of the L2 ('pronunciation norm'); and 4) acoustic investigation: the aim is to explore L2 production in fine-grained phonetic detail. The first two analyses have a focus on target-likeness whereas the focus of the other two analyses is on native-likeness.[2] The last two types of analysis enable us to explore not only the learner's ability to hit an identifiable L2 fricative, but also the ability to match native-speaker characteristics of realisation.

Another important issue relating L2 phonology is the notion of similarity and dissimilarity between L1 and L2 sounds. Sound comparison in L1 and L2 is commonly explored to make predictions regarding whether a similar or different sound is easier to learn. This comparison can be undertaken using various methods such as perceptual (e.g. Harnsberger, 2001b; Best and Tyler, 2007; Levy, 2009a), acoustic (e.g. Flege and Port, 1981; Cheon and Anderson, 2008), or phonological (e.g. Flege, 1992; Major and Kim, 1999). One important thing to note here is that similarity in one aspect of sound evaluation does not imply similarities in other aspects. For example, the /s/ phonemes in English, Japanese and Mandarin Chinese are similar in being represented by the same IPA phonemic transcription but different in their phonetic characteristics (Li *et al.*, 2007).

[1] This impressionistic analysis will be called 'sound identification task' in this study.
[2] Whereas acoustic analysis can also be used to investigate target-likeness, in this study the focus of acoustic analysis will be on native-likeness in order to be consistent with researchers who have used this analysis to investigate SLM-based predictions regarding the degree to which L2 learners achieve native-like production.

The investigation of L2 sound production is not only dependent on types of analysis, but also on whether or not internal and external factors are explored. For example, in the examination of language experience and consonantal context on perceptual assimilation of Parisian French (PF) /y/ and /œ/ by American English (AE) learners of French carried out by Levy (2009a), listeners with no experience or with formal instruction assimilated PF /y/ to /ʲu/ more often than those with formal-plus-immersion experience. Interestingly, these results were relevant in the bilabial but not alveolar context, pointing to the importance of looking at both internal and external factors.

Apart from challenges relating to L1 and L2 sound comparison, the analysis of L2 speech suffers from other shortcomings relating to how variable realisations are viewed. Many researchers believed that adult language learners cannot produce an L2 sound in a native-like manner due to the predominance of negative transfer from the L1 post-puberty (Scovel, 1969; Warsi, 2001). One reason for this conclusion relates to the analysis method, as most researchers combine all sound realisations produced by L2 learners into one group instead of separating categories of sound realisations (e.g., Flege *et al.*, 1997; Almbark, 2012; Liu and Jongman, 2012). For instance, when all realisations of an L2 sound by a given learner group are considered together, the percentage of target-like or native-like realisations is usually much lower than non-target-like or non-native-like ones. For example, Flege *et al.* (1997) examined English vowel production by German, Spanish, Mandarin and Korean speakers. The results from the forced-choice identification test showed that inexperienced Mandarin speakers had 60% of target-like [ɛ] and 58% of target-like [æ]. In their acoustic analysis, they only classified vowel realisations according to groups of speakers but not groups of sounds. The acoustic results showed no phonetic distinction in /ɛ/-/æ/ vowel contrast produced by Mandarin speakers, which seems to support a view of Warsi (2001) and Scovel (1969) that adult learners cannot attain native-like L2 sound production. However, when looking back at the result of forced-choice identification test, this claim might not be entirely supported as some productions were correctly identified as target-like, and potentially might be native-like. Another piece of evidence is from Munro (1993), who carried out an acoustic analysis of L2 vowels without classifying them according to whether or not they were target-like; the researcher mentioned that the findings from *t*-tests in his study should be taken with caution as some L2 learners in his study produced English vowels in native-like manner while others did not. These studies suggest that the decision regarding whether or not adult learners can achieve native-like realisations is not always clear-cut and needs to take variable realisations into consideration.

Only a few studies in L2 phonology have stratified sound realisations according to categories (e.g. target-like and non-target like) as well as speaker groups (e.g. Hanulíková and Weber, 2010; Yamaguchi, 2014). For instance, Hanulíková and Weber (2010) carried out a study exploring L2 English interdental fricatives produced by Dutch, German and English speakers using impressionistic and acoustic analyses. Results from the impressionistic analysis showed that L2 German speakers had fewer target-like realisations of /θ/ than L2 Dutch speakers. In their acoustic analyses, the data was analysed separately according to sound groups and speaker groups. The findings showed that acoustic characteristics of target-like realisations of /θ/ by native English speakers were more similar to those of L2 Dutch speakers than to those of L2 German speakers. Their findings suggest that L2 Dutch speakers not only had more target-like /θ/ than L2 German speakers, the acoustic characteristics of target-like /θ/ produced by L2 Dutch speakers were also more similar to that produced by native speakers of English than that produced by L2 German speakers.

Regarding acoustic methods of L2 sound analysis, scholars have used acoustic measurements to gain in-depth information on the phonetic details of L2 speech production (e.g., Flege *et al.*, 1997; Wayland, 1997; McAllister *et al.*, 1999; Almbark, 2012). These measurements have been claimed to help reveal some characteristics of speech data that are beyond human perception (Kent, 1996; Flege *et al.*, 1997; Edwards and Beckman, 2008). However, most researchers have tended to focus on studying vowels (e.g., Munro, 1993; Wayland, 1997; Flege *et al.*, 1999; Morrison, 2006; Drummond, 2010; Almbark, 2012) and stops (e.g., Flege and Eefting, 1987; Flege, 1991a; Antoniou *et al.*, 2010; Antoniou *et al.*, 2011). The fricative is an example of a sound that has rarely been investigated acoustically in the L2 phonological field, with only a few studies dedicated to it (Cheon, 2005; Cheon, 2006; Chang *et al.*, 2009; Hanulíková and Weber, 2010;

Spilková and Dommelen, 2010; Liu and Jongman, 2014). One reason is that the fricative category is a dense one and languages tend to differ greatly in number of fricative categories they have (Ladefoged and Maddieson, 1986), unlike stops which are more common in languages but do vary in aspirated/unaspirated and also in voiced/voiceless. Fricatives also tend to be more difficult to master as they require more precision in their articulation (the narrowing). Another reason is because L2 fricatives are often realised as other manners of articulation e.g. stop and affricate. In relation to the method of analysing sound realisations according to sound groups and speaker groups, acoustically analysing only realisations that are deemed target-like can solve this issue as it excludes sounds of other manners of articulation.

1.2 Focus and aims of the study

This study has the overall aim of investigating aspects of English fricative production by L2 Thai learners. The learners in this study were Thai L2 learners of English who lived in the L2 country for a short period of time while this study was carried out; however they had extensive exposure to the L2 in their home country for a long time. They had learned the L2 as a foreign language, i.e. using it mainly in classroom and had little use of it in their daily lives; their input was mostly provided by teachers with similar linguistic background to them. The focus is on English fricatives in word-initial position only, due to the lack of coda fricatives in Thai. The target fricatives in this study are divided into two main categories: shared and non-shared fricatives. The term 'shared' fricatives' refers to fricatives that exist in the phonological systems of native speakers of both L1 and L2, in this case i.e. /f, s/, whereas 'non-shared fricatives' are those that do not exist in the phonological system of the native language of the L2 learners, in this case /v, θ, ð, z, ʃ/.[3] There are three main aims as follows.

As social factors are found to play an important role in L2 phonology, the first aim concerns a sociolinguistic dimension, which is to determine factors which may influence L2 realisations that are deemed target-like. Regarding the study of

[3] (/ʒ/ and /h/ were excluded from this study as the former rarely occurs in English words and researchers have considered the latter as a vowel counterpart in many studies (e.g. Jongman et al., 2000).

English fricative production by Thai speakers, a range of factors are investigated in this area, including speech style (Brière and Chiachanpong, 1980; Chunsuvimol and Ronakiat, 2000; Chunsuvimol and Ronakiat, 2001; Burkardt, 2008; Roengpitya, 2011), word position (Brière and Chiachanpong, 1980; Chunsuvimol and Ronakiat, 2000; Chunsuvimol and Ronakiat, 2001; Burkardt, 2008; Roengpitya, 2011), years of study (Chunsuvimol and Ronakiat, 2000), age (Charmikorn, 1988; Pansottee, 1992), experience abroad (Charmikorn, 1988; Pansottee, 1992) and the gender of the speakers (Charmikorn, 1988). In addition, this study investigates all of these factors and more, looking at length of residence (LOR) and motivation in order to offer a comprehensive picture of potential influences on L2 realisations that are deemed target-like.

The second aim is to explore L2 fricative production using four different types of analysis. The first two analyses: impressionistic analysis and a sound identification task focus on target-likeness, whereas the focus of the other two analyses, accent rating task and acoustic analysis, is on native-likeness. In the impressionistic analysis, the author, who shares the same linguistic background as the L2 learners, examines the degree of target-like realisations of L2 as compared to L1 productions. In the sound identification task, although previous studies on L2 English fricative production by Thai learners have been carried out (e.g., Brière and Chiachanpong, 1980; Chunsuvimol and Ronakiat, 2000; Chunsuvimol and Ronakiat, 2001; Burkardt, 2008), none of them explored production as perceived by a group of native speakers of the L2. This study will be the first to involve a group of native listeners of L2 in listening to Thai L2 fricative production and identifying the sounds. In the accent rating task, the degree of accentedness of L2 production will be compared to productions by native speakers and evaluated by native listeners of the L2. The last analysis type is acoustic analysis, which aims to investigate L2 production at the phonetic level. The acoustic aspect of L2 fricative production has received little attention even though a number of impressionistic studies on L2 fricative production have been undertaken (e.g. Rau *et al.*, 2009; Mousa, 2014; Kaneko *et al.*, 2015). As realisations that are deemed target-like might sound accented or native-like (see Munro and Derwing, 1999) whereas the realisations that are deemed non-target-like have less potential to sound native-like, only realisations that are deemed target-like will be analysed in the accent rating task and acoustic analysis. This method of analysis is also more effective in addressing the issue of substitutions of target fricatives by sounds with different manners of articulation and investigating target-like production. It is hoped that each method will contribute to the overall understanding of the many facets of L2 sound production and its perception by native speakers.

The last aim is to examine models, namely CAH and SLM,[4] in terms of the extent to which they can account for the results in this study. The main area of agreement in the current models is the influence of L1 sound patterns on L2 sound production. There are still some outstanding questions: 1) To what extent does L1 influence L2 production? 2) To what extent can L2 learners attain target-like and native-like L2 production? 3) What factors are related to target-like production? This study aims to establish how each of the current models explains the production of L2 Thai learners of English who have mainly acquired English in the L1 country.

1.3 Importance of the study

A number of challenges for researchers working on L2 phonology were pointed out in 1.1. This study addresses these and is one of few studies on the acoustic characteristics of L2 fricative production. This study describes these characteristics in a number of acoustic measurements and compares them with those of L2 English fricatives as produced by native British English speakers and native Thai fricatives as produced by Thai native speakers (where applicable). The results will be beneficial to other researchers interested in L2 fricatives as produced by L2 learners of other language backgrounds.

The next contribution is that this study investigates L2 fricative production by L2 Thai learners in comparison to the productions of native speakers of L2 and L1 (for shared fricatives). Most previous studies on L2 phonology have only compared L2 production to the production of native speakers of L2 (Zampini, 2008). Including the productions of both groups of native speakers for shared fricatives will allow in-

[4] PAM-L2 and L2LP focus on perception of L2 sound contrast, and thus seem less relevant to the present study.

depth exploration of whether the L2 sound is both phonetically and phonologically similar to the L1 sound produced in the native language.

This study contributes to the study on the degree of target-likeness of L2 English fricative production by L2 Thai learners as perceived by a group of native listeners of L2. Even though a number of studies on L2 English fricatives by L2 Thai learners have been carried out (e.g. Brière and Chiachanpong, 1980; Chunsuvimol and Ronakiat, 2000; Chunsuvimol and Ronakiat, 2001; Burkardt, 2008), they were impressionistic studies and did not investigate the L2 fricatives via perception of native listeners of the L2. In this study, to establish the degree to which L2 learners' productions are identified as target-like, a group of native listeners of L2 were engaged in a sound identification task.

Furthermore, this study also contributes to the investigation of native-likeness in L2 production by examining the degree of accentedness of L2 productions that are deemed target-like as compared to target-like L1 productions.[5] Regarding shared fricatives, researchers studying English fricative production by L2 Thai learners usually claim that these learners have no difficulties producing them because they exist in Thai phonology (Ronakiat, 2002; Kanokpermpoon, 2004). The results of this study might reveal some results which either support or contradict to this claim. It is possible that even though realisations that are deemed target-like are transcribed using the same phonemic IPA symbol in impressionistic analysis, these might not sound exactly the same for native speakers of L2. The results will also reveal the degree of native-like realisations that are deemed target-like for non-shared fricatives.

To contribute to the sociolinguistic investigation of English fricative production by L2 Thai learners, this study will explore factors that correlate with target-like production. A few studies (Brière and Chiachanpong, 1980; Charmikorn, 1988; Pansottee, 1992; Chunsuvimol and Ronakiat, 2000; Chunsuvimol and Ronakiat, 2001; Burkardt, 2008; Roengpitya, 2011) have investigated this; however, the number of factors considered was small. This study is the first to combine a number

[5] In this thesis, 'accentedness' is used interchangeably with 'non-native-likeness'.

of factors relevant to L2 speech learning to determine if any of them correlate with target-like L2 production.

The last contribution of this study is the comparison of native Thai and British English fricatives. Thai fricatives have received little attention from researchers – there have been only two previous studies (Harris, 1972; Roengpitya, 2011). Harris (1972) carried out an impressionistic study on Thai initial consonants, whereas Roengpitya (2011) conducted a small-scale acoustic study. However, knowledge of L2 acquisition of Thai fricatives is still lacking and they need to be investigated. This study will provide empirical findings on Thai fricatives in comparison to British English fricatives from four types of analyses: impressionistic, sound identification, accent rating and acoustic; it is hoped that this will benefit future researchers who are interested in comparing these two fricatives with fricatives of other languages.

1.4 Research questions

The focus of this study is on exploring L2 English fricative production by L2 Thai learners. There are four research questions, which relate to each target fricative, as follows:

1. What are the factors related to realisations of L2 English fricatives that are deemed target-like as produced by Thai learners? (Chapter Three)
2. To what extent is the production of L2 English fricatives by Thai learners deemed target-like or deemed to fit that category?

    2.1 To what extent are L2 English fricatives deemed target-like as perceived by the author, who is a phonetician with a similar linguistic background as L2 Thai learners, in an impressionistic task? (Chapter Three)

    2.2 To what extent are L2 English fricatives deemed target-like as perceived by a group of native speakers of the L2 in a sound identification task? (Chapter Four)

3. To what extent are L2 English fricative realisations that are deemed target-like also native-like?

3.1 To what extent are L2 English fricative realisations as produced by L2 Thai learners accented even when they are deemed target-like? (Chapter Five)

3.2 To what extent are acoustic characteristics of L2 English fricative realisations that are deemed target-like similar to those of native English and native Thai (if applicable) fricatives? (Chapter Six)

4. To what extent do current models, namely the Contrastive Analysis Hypothesis (CAH) and the Speech Learning Model (SLM) account for the results of the L2 speech production in this study? (Chapter Seven)

1.5 Organisation of the study

This study comprises seven chapters. Following this introduction, Chapter Two presents related literature on current models of L2 speech learning. Four popular models – the Contrastive Analysis Hypothesis (CAH), the Perceptual Assimilation Model-2 (PAM-2), the Speech Learning Model (SLM) and Second-Language Linguistic Perception (L2LP) – are described and critiqued in terms of their potential value to this study. This chapter also presents internal and external factors related to L2 speech learning. It concludes by examining fricatives, including the acoustic characteristics of fricatives, fricatives in Thai and English and previous studies on the use of English fricatives by L2 Thai learners.

Chapter Three is designed to answer the first and second research questions, i.e. speech realisation viewed from the perspective of impressionistic study (as perceived by the author) (research question 2.1) and the relationship between production that is deemed target-like and external factors (research question 1). These two analyses should be in different sections, but are contained within the same chapter as they are relevant to one another: the realisations that are deemed target-like as derived from the impressionistic study are considered in the sociolinguistic section. The L2 realisations are first judged in terms of whether they are target-like or not as compared with L1 realisations by native speakers. Following that, these realisations will be investigated for their relation to certain factors known to influence L2 learning. The factors investigated in this chapter include motivation (ideal L2 self, ought-to L2 self, L2 experience, L2 anxiety), vowel context, gender, LOR, English exposure and word frequency. To provide a closer examination of factors in L2 learning, semi-structured interviews were used to obtain qualitative information regarding the participants' attitudes and personal life-styles.

Chapter Four explores the degree of target-likeness of L2 fricative production as perceived by native speakers of the L2 (research question 2.2). For the analysis in this chapter, English native speakers were asked to listen to randomised stimuli that were produced by L2 learners and native speakers of L1 as controls, to identify the words they were hearing. This chapter provides an insight into the degree to which L2 segments are identified as the intended targets by L1 listeners.

Chapter Five presents an investigation of the degree of native-like production of L2 English fricatives and compares these with the production of native speakers of the L1 and L2 using an accent rating task (research question 3.1) and focusing on target-like realisations.

Chapter Six examines the acoustic characteristics of L2 fricatives (research question 3.2). As the fricative involves complex articulation, the investigations were carried out with a number of acoustic parameters, such as centroid, Standard deviation (SD) and peak location. In this chapter, the acoustic characteristics of L2 realisations that are deemed target-like are compared to those of native English fricatives produced by native speakers of English and those of native Thai fricatives produced by native speakers of Thai (for shared fricatives).

Chapter Seven contains the discussion, which considers the extent to which current well-known models: CAH and SLM can account for the results of this study and how the results can contribute to the current models (research question 4). The final part of this chapter presents the overall conclusions, directions for future work and limitations of the study.

Chapter 2. Review of the literature

2.1 Introduction

As the main aim of this study is to investigate L2 English fricative production by L2 Thai learners, this chapter begins by describing influential models of L2 speech learning. In section 2.2, four well-known models are presented: the Contrastive Analysis Hypothesis (CAH), the Perceptual Assimilation Model-L2 (PAM-L2), the Speech Learning Model (SLM) and the Second-Language Linguistic Perception (L2LP). The extent to which current theories of L2 learning can account for L2 fricative learning by Thai learners of English is then evaluated.

Section 2.3 describes internal and external factors related to L2 learning. Following Tagliamonte (2013), internal factors refer to linguistic factors, e.g. word frequency and vowel context, whereas external factors are social and situational factors influencing L2 learning, e.g. motivation, amount of English exposure and so forth.

A review of the acoustic characteristics of fricatives is given in section 2.4. This section details the acoustic properties of fricatives as well as some techniques in fricative analysis. As this study concerns fricatives in Thai and English, the description of fricatives in these languages appears in section 2.5, and is then used as a baseline to examine the articulatory and acoustic properties of L2 fricative production. Section 2.6 evaluates previous studies on L2 English fricatives produced by Thai learners. Finally, section 2.7 identifies research gaps which will be addressed in this study.

2.2 Significant models of L2 phonology

Four influential models which account for the perception and/or production of non-native sounds are the Contrastive Analysis Hypothesis (CAH), the Perceptual Assimilation Model (PAM), the Speech Learning Model (SLM) and the Second-Language Linguistic Perception (L2LP). The details of each model are presented in turn.

2.2.1 Contrastive Analysis Hypothesis (CAH)

CAH was introduced by Lado (1957), who proposed that L2 learners tend to transfer the native phonological system in the process of L2 learning. This theory accounts for L2 pronunciation by considering whether a distinct unit of sound (phoneme) exists in the native sound system. CAH proposes that learners will find L2 sounds easy to learn when they are similar in three respects: i) phonemic existence; ii) structure; iii) distribution. In contrast, L2 sounds that are different in terms of these three aspects will be difficult to learn.

The first term 'phonemic existence' relates to whether a similar phoneme exists in the native sound system. For example, Thai learners are reported to find voiced fricatives, /v, ð, z, ʒ/, in English difficult as they do not occur in Thai (Kanokpermpoon, 2007). The second term, 'structure', refers to the allophonic status of a given sound when it exists in the native sound system. For example, although one might expect Spanish learners to find English /d/ easy to pronounce as it occurs in Spanish, they in fact find it difficult to pronounce /d/ as target-like in intervocalic position and following /r/ because these are the contexts in which Spanish /d/ is realised as a dental fricative [ð]. The allophonic status of [ð] in this context leads to mispronunciation of /d/, resulting in the mispronunciation of the pair 'ladder' and 'lather' (Moore and Marzano, 1979). The third term 'distribution' signifies the position of the phoneme in a syllable. For instance, Thai learners of English may find it difficult to pronounce /f/ in final position as it is impermissible in Thai (Chunsuvimol and Ronakiat, 2000).

During the period that followed the spread of the CAH, most studies were carried out using impressionistic analysis by researchers or transcribers who adopted a phonemic or a broad phonetic approach to the transcription of L2 sound realisation (e.g., Walz, 1980; Zampini, 1994; Musau, 1999). At that time, researchers were interested in whether the L2 sounds realised were target-like or not. For example, Walz (1980) investigated French sound production by L2 English speakers. The sounds tested were believed to be difficult for Americans either because they did not occur in the English phonological system (e.g. /ɛ̃, ã, ɔ̃/) or because they broke English phonotactic rules, e.g. the maintenance of vowel production in the unstressed syllable in French which English speakers usually reduce to /ə/. These sounds were selected based on differences in the cross-linguistic sound systems of L1 and L2. The author transcribed the productions and reported the results in percentage of target-like production. The nasal vowels, for instance, were reported to have an accuracy rate of 50-80%, with the nasalisation of /ɛ̃/ being reduced or an insertion of a nasal consonant to replace the nasalisation being applied. The /ɛ̃/ was also pronounced as [ã] whereas /ã/ was produced as [ɔ̃].

CAH effectively explain many of the pronunciation problems experienced by L2 learners, as the majority of studies on L2 learning show that the difficulty that L2 learners experience often arises from differences between the L1 and L2; however, the popularity of this model has declined due to three main problems: i) similarity between two languages might be only ‘a degree of shared similarity’ rather than ‘absolute identity’ (James, 1980, p. 168) – the description of similar and different sounds is vague when based merely on a phonemic inventory; ii) CAH does not explain all errors made by L2 learners (Sridhar, 1980); iii) CAH does not take the wide range of L2 production (variability of factors such as categories of sound realisations or speakers) into consideration (Dickerson, 1974), even though variability usually relates to the stage of L2 learning. Nevertheless, CAH is useful for this study in terms of predicting the areas of difficulty in the impressionistic analysis that Thai learners may face with English fricatives due to differences in phonemic inventories. English has a relatively large number of fricatives, including /f, v, θ, ð, s, z, ʃ, ʒ, h/; Thai, on the other hand, has a much smaller inventory, including only /f, s, h/. Based on this difference in sound systems in the initial position, the hypothesis linked to CAH is that Thai learners will find /v, θ, ð, z, ʃ, ʒ/ difficult, but /f, s, h/ will be easy to articulate based on an impressionistic analysis.

Next, I turn to the other two models, the Perceptual Assimilation Model-L2 and the Speech Learning Model. These two models were developed as the interest of researchers changed from target-likeness to native-likeness.

2.2.2 Perceptual Assimilation Model-L2 (PAM-L2)

The Perceptual Assimilation Model-L2 (PAM-L2) was developed by Best and Tyler (2007). It originated from the Perceptual Assimilation Model (PAM), which is a perception-based rather than a production-based model. According to PAM, speech perception is based on articulatory gestures in speech production (Best, 1994b; Best, 1994a; Best, 1995). PAM suggests that learners with little or no experience in L2 (in other words 'naïve listeners') fail to discriminate non-native sounds when the sound contrast shares similar articulators as the native one. For example, a Zulu contrast – a voiced bilabial plosive versus implosive distinction was predicted to assimilate to English /b/ as these two non-native sounds occur in the same place of constriction as English /b/.

Best and Tyler (2007) later extended the focus of PAM from only non-native listeners, who are naïve listeners, to L2 learners and called the new version PAM-L2. Unlike non-native listeners, L2 learners are actively learning a target language to achieve wide-ranging purposes, such as to fulfil functional, communicative and educational requirements. The interest of PAM-L2 lies in 'natural communicative situations' (Best and Tyler, 2007, p. 17) rather than controlled situations such as the classroom.

This new model gives importance to all articulatory, phonetic, and phonological differences between the L1 and L2. The application of PAM-L2 to L2 learners leads to four predictions regarding contrast perception:

1. Two-category (TC) assimilation: both L2 phonological categories are perceived as equivalent (perceptually assimilated) to given L1 phonological categories. For example, the North German vowels /iː, i/ are equally perceived as the American English vowels /iː, i/ despite differences in their phonetic realisations (Strange *et al.*, 2004).

2. Category goodness (CG) assimilation: both L2 phonological categories are perceived as equivalent to the same L1 phonological category, but one is perceived as being more deviant than the other. For example, Japanese listeners show CG assimilation of the English /w/-/r/ contrast as they perceive this pair as /w/ (Best and Strange, 1992).

3. Single-category (SC) assimilation: both L2 phonological categories are perceived as equivalent to the same L1 phonological category, but as

equally good or poor instances of that category. For example, Japanese listeners assimilate English /r/ and /l/ as poor examples of a single phoneme /ɾ/ in Japanese (Takagi and Mann, 1995).

4. Uncategorised-uncategorised (UU) assimilation: there is no L1–L2 phonological assimilation because the L2 sound cannot be assigned to any L1 category. This applies, for example, to non-native listeners discriminating Zulu voiceless unaspirated apical versus lateral clicks, /ǀa/-/ǁa/ respectively (Best *et al.*, 1995).

Before making predictions, L2 learners are normally asked to classify L2 sounds in terms of their closet L1 sounds (assimilation task) and to rate similarity of the vowels in L1 and L2 using a rating scale (goodness rating). Then the percentage of vowel classification and goodness rating are used as criteria for classifying L2 sound contrast into one of the four assimilations above. However, PAM-L2 does not provide the ranges of recommended scales to be used for goodness ratings to classify L2 sound contrast, resulting in subjective predictions which can be varied in different studies (See Levy, 2009b; Almbark, 2012).

The PAM-L2 also focuses on the learning context of the L2 learners, which includes word frequency, vocabulary size, amount of L2 exposure and input from native speakers of L2 (Best and Tyler, 2007, p. 15). Some studies provide support for the predictions of PAM-L2 (e.g. Fabra, 2009; Bundgaard-Nielsen *et al.*, 2011; Rallo Fabra and Romero, 2012). For example, Rallo Fabra and Romero (2012) carried out a categorical discrimination test to investigate the perception of English vowel contrasts by Catalan learners with varying degree of English proficiency. Based on assimilation patterns of English vowels to Catalan vowels (Best and Tyler, 2007), the English /ɑ/-/ʌ/ vowel pair was subject to single-category assimilation, as 64% of English /ɑ/ was identified as Catalan /a/ whereas 47% of English /ɑ/ was identified as Catalan /a/; hence the discrimination rate should be poor. The finding of Rallo Fabra and Romero (2012) showed that the overall discrimination of English /ɑ/-/ʌ/ was poor because both vowels were assimilated to a single Catalan category /a/ as predicted by PAM-L2, but the scores for discrimination were highest in proficient learners, followed by mid-proficient and low-proficient, respectively. Another example is from Bundgaard-Nielsen *et al.* (2011) which investigates the effect of vocabulary size on the perception of L2 Western Sydney Australian English (AusE$_{WS}$) vowels by Japanese learners. In a preliminary investigation of the relationship between L2 perception and vocabulary size, five out of 18 AusE$_{WS}$ vowels were classified as uncategorised: /ɜː, æ, oː, æɔ, əʉ/. When looking at the percentage of the three most selected Japanese categories for the five uncategorised AusE$_{WS}$ vowels, a group of Japanese learners with large vocabulary scores always had a higher percentage of categorisation than the group of the learners with low vocabulary scores, suggesting that the high vocabulary group was more consistent in their identification in terms of L1 assimilation scores and the number of alternative L1 categories they selected for each L2 vowels as opposed to the low vocabulary group. It also supports the notion that vocabulary size affects L2 phonological reattunement.

Although the focus on PAM-L2 is on perception, some scholars have extended it to production (e.g. Antoniou *et al.*, 2010; Antoniou *et al.*, 2011). For example, Antoniou *et al.* (2011) explored the voice onset times (VOTs) of Greek-English bilinguals' productions of /b, d, p, t/. The productions were investigated in either Greek or English unilingual mode and in code-switching mode. The finding showed that the bilinguals' productions of stop VOTs in both the L1 and L2 were not different from those of monolinguals, suggesting the formation of language-specific phonetic categories in PAM-L2. According to the authors, PAM uses Articulatory Phonology (Browman and Goldstein, 1989; Browman and Goldstein, 1990; Browman and Goldstein, 1992; Browman and Goldstein, 1995) to link production and perception. According to this framework, the phonological form that users produce and perceive must be similar. Speaker and listener draw on the same mental representation. If not the listener will not be able to analyse the linguistic content. The listener also has to accurately perceive the language form that is produced by the speaker; hence the sent phonological message and the received one must be equivalent. However, it is not clear how these authors relate the mechanisms of production and perception.

2.2.3 Speech Learning Model (SLM)

The Speech Learning Model (SLM) was developed by Flege and colleagues with the purpose of explaining changes across the life span in L2 speech learning (Flege, 1995). It deals with both phonological and phonetic properties of the L2. This framework focuses on experienced bilinguals who have used L2 for many years rather than beginners and it emphasises the importance of perception as the source of production. This model thus shows a relationship between perception and production: if the listeners cannot accurately perceive an L2 sound, they cannot correctly produce it. However, it does not claim that inaccurate production occurs from misperception.

In addition, Flege (1992) divided L2 sounds into three types: new, similar and identical. 'New' refers to L2 sounds which have no counterpart in the L1 and are acoustically different from sounds in L1; for example, French /y/ is considered 'new' for English speakers. 'Similar' refers to an L2 sound which is phonemically similar to L1, but phonetically different, such as /t/ in both French and English; in French, this sound is a short-lag stop produced in the dental area, whereas in English, it is a long-lag stop produced in the alveolar area. 'Identical' relates to an L2 sound which is identical to an L1 sound both phonetically and phonemically. According to Flege, regarding the three–type classification of L2 sounds, when the L2 sound is transcribed using a different IPA symbol that does not exist in the L1 sound system, this L2 sound is classified as 'new'. On the other hand, when the L2 sound is transcribed using an IPA symbol used in the L1 sound system, this L2 sound can be classified as either 'similar' or 'identical' depending on the phonetic qualities. The classification of the L2 sound produced by native speakers as new, similar or identical in this model lies behind the predictions regarding whether this sound will be difficult or easy to learn. In SLM, a different sound is easier to learn than a similar sound. Hence, the hypothesis is that L2 shared fricatives will be difficult for L2 Thai learners to produce, whereas L2 non-shared fricatives will be easy. However, even though the similarities and differences between L1 and L2 sounds is also based on both IPA symbols and phonetic qualities, in the acoustic investigation where many acoustic measurements are used, it is often difficult to pinpoint if the phonetic characteristics of L1 and L2 sounds are similar or different.

Classifying L2 sounds into easy or difficult seems to be similar to representing L2 sound with phonemic IPA symbols, which is rather discrete, whereas L1 and L2 sound comparison is rather similar to a continuum and more complicated. For example, when examining various acoustic measurements, some acoustic characteristics might promote a conclusion of similarity of L1 and L2 sounds whereas some other characteristics might promote a difference.

Regarding predictions on outcomes for learners, SLM postulates that:

1. Learners will have the same mechanisms and processes that they use for their L1 learning their whole lives to use for L2 learning.

2. Phonetic categories are the unique characteristics of sounds which exist in long-term memory.

3. As learners develop their languages throughout their lives, the specific phonetic aspects of the L1 or L2 sounds evolve.

4. Bilinguals maintain contrasts between L1 and L2 phones, whereas these phones are in the same phonological space.

In addition, the model proposes seven hypotheses:

1. Learners are sensitive to differences between L1 and L2 sounds allophonically rather than phonemically, e.g. when they are located in specific positions, such as onset or coda.

2. If bilinguals notice differences between L1 and L2 sounds, it is likely that they will create a new phonetic category for an L2 sound that is dissimilar from an L1 sound.

3. The greater the differences between L1 and L2 sounds perceived by L2 learners, the easier it will be for bilinguals to acquire the L2 sounds.

4. The younger the age of learning (AOL) of L2 learners, the easier it will be for them to acquire the L2.

5. The ‘mechanism of equivalence classification’ (Flege, 1995, p. 239) may inhibit the ability of bilinguals to discriminate specific L2 sounds. If this is the case, a diaphone (Flege, 1995, p. 239), defined as two sounds (one in L1 and the other in L2) that are linked to one another in perception will show similar phonetic properties in production, e.g. an L1 sound with L2 sound quality.

6. There might be a difference in terms of the phonetic category between sounds produced by bilinguals and monolinguals. Bilinguals will also try to maintain the phonetic contrast between categories in a shared L1–L2 phonological space.

7. Finally, bilinguals will be able to produce native-like L2 sounds.

With respect to the first hypothesis, the context in which phonemes occur is important for L2 perception (e.g. Dupoux *et al.*, 1997; Harnsberger, 2001a; Boomershine *et al.*, 2008). For example, Japanese listeners discriminate the English consonant /ɹ/–/l/ contrast better when it is located in word-final position than in word-initial position, though generally they have difficulty differentiating these two sounds (Logan *et al.*, 1991; Strange, 1992).

The second hypothesis states that a new sound category will be created when the L2 learners recognise some phonetic differences between L1 and L2 sounds; otherwise, a new category will not be created. Support for this claim can be found in various studies (e.g. Bradlow *et al.*, 1997; MacKay *et al.*, 2001; Lacabex *et al.*, 2008). For instance, Lacabex et al. (2008) investigated the perception of English /ə/ by Spanish learners of English. Subjects were divided into three groups: a control group (not given specific training), a perceptual training group (offered training based on discriminatory exercises) and a production group (provided with articulatory and visual cues and feedback). The findings showed that both experimental groups had significantly improved scores for schwa perception at word level. The development of the perception of schwa at word level shows support for the second hypothesis, namely that a new sound category is created when L2 learners find differences between L1 and L2.

The third hypothesis proposes that the degree of recognition of phonetic differences between L1 and L2 sounds depends on the degree of perceptual differences between L1 and L2 sounds. One piece of evidence for this hypothesis is the perception of Japanese /r/, which is perceived as more similar to English /l/ than /ɹ/ (Sekiyama and Tohkura, 1993). It is assumed that Japanese listeners will be more likely to recognise the differences between English /ɹ/ and Japanese /r/ rather than English /l/ and Japanese /r/.

According to the fourth hypothesis, an increase in AOL leads to poorer recognition of the phonetic differences between L1 and L2 sounds. A large number of research studies support this hypothesis (e.g. Flege, 1991a; Flege *et al.*, 1995a; Munro *et al.*, 1996; Flege *et al.*, 1999; MacKay *et al.*, 2001; Piske *et al.*, 2002; Jia *et al.*, 2006). For example, Flege *et al.* (1995a) investigated the importance of AOL and the level of production of English /ɹ, θ, ð/ in initial position by native speakers of Italian. The participants comprised two groups: Italian native speakers and English native speakers. The native speakers of Italian had lived in Canada since the age of 2–23 years old (average age 13 years) and had been there for 15–44 years (average length of residence 32 years). The results showed that the percentage of production of these three sounds decreased with the increase of AOL. The finding that AOL is significant for /ɹ, θ, ð/ production is assumed to be due to the following: i) the younger learners have better motor ability to produce new sounds; ii) the perception of phonetic differences between new L2 sounds decreases with increasing age; iii) positive attitudes and motivation.

The fifth hypothesis suggests that because of equivalence classification, a new sound category for L2 might not be created. Instead, a single sound category that represents both the L1 sound and new L2 sound that learners perceive as similar will be used. This mechanism prevents L2 learners from forming L2 phonetic categories, which results in the merging of acoustic properties of L1 and L2 (Flege, 1991b). This will in turn affect L2 production in that the learners will use this single sound for both L1 and L2 production (e.g. Flege and Hillenbrand, 1984; Flege, 1987; Bohn and Flege, 1992; Fowler *et al.*, 2008; McCarthy *et al.*, 2013). Flege *et al.* (2003) tested whether bilinguals who assimilate Canadian English /e$^{\text{ɪ}}$/ as Italian /e/ will fail to create a category for Canadian English /e$^{\text{ɪ}}$/ despite the fact that

English /e^{ɪ}/ is produced with more formant movement than Italian /e/, suggesting that it is more diphthong-like and that these two sounds were perceptually different from one another. The participants were Italian-English bilinguals who were born in Italy but migrated to Canada between the ages of two and 30 years. The findings confirmed that these bilinguals produced Canadian English /e^{ɪ}/ in a less diphthong-like manner in their vowel acoustic properties. The authors suggested that this is because they treat Canadian English /e^{ɪ}/ as Italian /e/, merging the properties of the first vowel with those of the second vowel due to the mechanism of category assimilation.

In the sixth hypothesis, Flege (1995) also proposed that the phonetic properties of L2 sounds produced by bilinguals can be different from the same sounds produced by L1 monolinguals in the following cases: i) bilinguals maintain contrasts in L1 and L2 which share in the same phonological space by having different bilingual L2 categories from L1 categories; or ii) the bilingual's category is based on different features from the monolingual's categories. Some studies have supported the notion of differences in the phonetic properties of L2 sounds produced by bilinguals and monolinguals (e.g. Flege, 1987; Baker and Trofimovich, 2005; Fowler *et al.*, 2008). In a study by Fowler *et al.* (2008) exploring cross-linguistic influences in the speech of bilinguals, three groups of bilinguals produced 10 sentences with 30 target words to investigate their VOTs of /p, t, k/. The three groups comprised: i) French-English bilinguals from birth; ii) French-English bilinguals with English as their L1 and French as their L2; iii) French-English bilinguals with French as their L1 and English as their L2. The findings showed that the VOTs by monolinguals of French /p/ were shorter than English /p^{h}/. Although the VOTs for the bilingual speakers across groups were significantly shorter for English monolinguals, VOTs for French by bilingual speakers were significantly longer than those produced by French monolinguals. Also, the VOTs for English by bilingual speakers were significantly shorter than those by English monolingual speakers. For all voiceless stops, bilinguals nonetheless maintained the contrasts of voiceless stops in English and French.

In the last hypothesis, SLM claims that the L2 category will be articulated with phonetic properties that are similar to the phonetic qualities of L2 sound produced by native speakers of L2. This hypothesis suggests L2 learning. In a study by Sturm (2013), advanced learners of L2 French significantly improved their pronunciation after being trained in a French phonetics and pronunciation course; this was exhibited in many aspects: syllabification, accentuation and intonation, consonants, liaison, vowels, semi-vowels, nasal vowels and consonants, and schwa, suggesting that L2 learners can master their L2 production ability if given appropriate input.

Of the seven hypotheses above, four are related to this study. The second hypothesis concerning the learning of new sounds, which are /v, θ, ð, z, ʃ/, is supported if the L2 Thai learners produce L2 English fricatives with similar phonetic properties to the L2 English fricatives produced by the native speakers of English. The fifth hypothesis is related to shared fricatives, which is supported if the acoustic qualities of native English /f/ and /s/ are different from those of native Thai /f/ and /s/ and the Thai learners produce /f/ and /s/ with similar acoustic qualities as when they produce their native Thai /f/ and /s/. The sixth hypothesis relates to both shared and non-shared fricatives, which is supported if the phonetic categories of L2 English fricatives produced by the Thai learners are different from those of native English and native Thai fricatives, regardless of whether these L1 fricatives are different from each other or not. The last hypothesis concerns both shared and non-shared fricatives, predicting that the acoustic qualities of L2 English fricatives are similar to native English fricatives.

As stated in the introduction, the great difference between research around the period when CAH was popular and more studies since SLM and PAM-L2 became more popular is that CAH researchers mainly focused on target-likeness using phonemic transcription whereas SLM and PAM-L2 researchers are interested in whether the L2 production is target-like through the perception of native speakers of L2 and whether it is native-like through accent rating and acoustic analysis – whether it is understandable to native listeners of L2, as well as the extent to which this is so. Hence, researchers in the later stages of L2 phonology research have viewed L2 speech production from more comprehensive perspectives than in the earlier stage.

2.2.4 Second-Language Linguistic Perception (L2LP)

The latest model of all four models is the Second-Language Linguistic Perception (L2LP) which was developed by Escudero (2005). The model aims to describe, account for and predict L2 sound perception for the whole developmental process. It bases its predictions on the comparison of L1 and L2 sound contrasts. Five main ingredients relating to successful L2 learning are purposed: optimal L1 and target L2, initial state, learning task, development and end state.

With regards to the first ingredient: optimal L1 perception is the learner's best perception of L1 sound categories and target L2 optimal perception is the L2 speaker's best perception of the L2 sound categories. The optimal perception of both L1 and L2 can be found via that of native speakers of each language. For example, in speaking, F1 of /ɛ/ for Canadian English (CE) is 550-600 Hz. For /æ/, F1 for CE is between 800-900 Hz whereas that for Canadian French (CF) is between 650-800 Hz. In listening, for /ɛ/, native speakers of CE perceive this vowel when the F1 is between 600-700 Hz whereas native speakers of CF perceive this vowel when the F1 is between 550-600 Hz. For /æ/, in listening, native speakers of CE perceive this vowel when the F1 is between 800-900 Hz whereas those of CF perceive this vowel when the F1 is between 650-800 Hz. When listening to tokens with F1 between 637-757 Hz, native speakers of CE will categorise them as /ɛ/ whereas those of CF will categorise them as /æ/. By measuring the perceived ranges of L1 and L2 sound categories, we have data for L1 and L2 optimal perception. Many studies support the L2LP claim that the acoustic properties of the L1 and L2 sounds as produced by native speakers of each language should determine the perception of L2 sound contrast by L2 listeners (e.g., Gilichinskaya and Strange, 2010; Escudero and Vasiliev, 2011; Escudero and Williams, 2012).

The second ingredient is the L2 initial state, which is the starting point of the L2 learning when listeners have no prior knowledge of that language. L2LP proposes the Full Copying hypothesis which refers to the equating of L2 sound to L1 sound. This ingredient is a stage at which the learner perceives L2 sounds under the L1 abstract categories and perception grammar. For example, Spanish learners of Southern British English (SBE) perceive SBE /i/ and /ɪ/ as Spanish /i/ because 1) the F1 of these two SBE vowels are in the range of the perception of Spanish /i/; and 2) the difference in duration between two SBE vowels is not perceived by Spanish learners. This hypothesis is similar to the concept of L1 transfer in CAH (Lado, 1957), equivalence classification in SLM (Flege, 1995) and two-category assimilation in PAM-L2 (Best and Tyler, 2007).

The third ingredient is the L2 learning task. Two tasks are purposed: L2LP perceptual task and L2 representational task. The former involves the learner changing the shape of their L1 boundaries to those of the target L2 sound. For example, Spanish leaners of English have to perceive the differences of the SBE /i/ and /ɪ/ to recognise them. As duration is not an auditory cue in the Spanish vowel system, learners have to create new perceptual mappings (creating new phonological representations) for these two vowels. And as the F1 of Spanish /i/ is different from SBE /i/ and /ɪ/, learners have to split their L1 perceptual mappings (adjusting the existing perceptual mappings) to learn these two vowels. In the L2 representational task, learners create the L2 sound via the lexical representation of two words. For example, to acquire SBE /i/ and /ɪ/, Spanish learners have to learn to distinguish words like 'sheep' and 'ship'. Wanrooij *et al.* (2013) found support for the L2 representational task in that Spanish learners of L2 Dutch improved their perception in the direction of the Dutch contrast /ɑ/-/aː/after training in this contrast via words representing the contrast.

The description of perception of what the learner starts with and what the learner aims to achieve enables us to predict and account for the development of L2 sound perception, i.e. the fourth ingredient, development. This ingredient refers to learners' use of the same learning mechanisms they use in their L1 sound perception. They will start to categorise new L2 sounds through auditory-driven learning which applies to acoustic dimensions that do not occur in their native language, such as when Spanish learners learn durational differences to differentiate /i/ and /ɪ/ in SBE. Under at Optimality Theory account (Prince and Smolensky, 1993), with the help of lexical representations in L2, learners will rerank their L1 learning constraints to comply with the L2 rankings, i.e. adjusting their perceptual mappings to match those of the L2 sounds.[6] For example, for the SBE /i/ and /ɪ/ learning of Spanish, they will create perceptual mappings that link vowel duration values to create two vowels that are different in length.

The last ingredient is the L2 end state. L2LP has two predictions for the L2 end state: learners reach optimal target L2 sound perception or their L1 sound perception remains optimal over L2 perception. According to this model, the L1 and L2 categories are in separate grammar systems. When the L2 input is rich and because they are equipped with some cognitive plasticity, L2 learners can optimise their target L2 perception. For advanced L2 learners, L2 perception is exhibited in a similar way to that of monolingual native listeners. Not only does no fossilisation occur in L2 sound perception, but the L1 sound perception also remains the same.

Regarding various L2 sound contrasts, three scenarios are purposed. First, the new scenario is a situation when the number of the L1 sound contrasts is smaller than the L2 sound contrasts, e.g. when both SBE /i/ and /ɪ/ are perceived as /i/ in Spanish. Second, the similar scenario is a situation when the number of L1 sound contrasts is equal to the number of the L2 sound contrasts, e.g. when the L2 Canadian French vowel contrast /ɛ/-/æ/ is classified as /ɛ/ and /æ/ in L1 Canadian English where both might overlap in perception as the same vowel in L1. Last, is the subset scenario which is not included in any other model. This is when the L2 sound contrast is perceived as more than two sounds in L1 perception, e.g. L2 Spanish /i/ and /e/ are perceived as /i/ and /ɛ/ in L1 Dutch, respectively, and these two L2 contrasts are also perceived as /ɪ/ in L1 Dutch. From these three scenarios, the new scenario presents learners with the most difficulties, followed by the subset scenario and the similar scenario.

2.2.5 L2 speech models: summary and gaps

Each of the models discussed above has different aims: i) CAH aims to account for L2 error – both production and perception based on L1 interference; ii) PAM-L2 aims to account for the perception of non-native sound contrasts by L2 listeners; iii) SLM aims to explain changes in L2 speech learning across the life span, mainly

[6] Optimality Theory a model that says that the final form of language is a result of the interactions between constraints (Prince and Smolensky, 1993).

on perception but it also shows the link with production; iv) L2LP aims to account for L2 sound perception of L2 sound contrasts in all stages, i.e. initial states developmental and end state. However, they are similar in that they accept the influence of L1 on L2 speech learning. In addition, CAH and SLM both focus on production and perception whereas PAM-L2 and L2LP focus on only perception. When comparing aspects of sounds between L1 and L2 to make predictions concerning whether a similar sound or different sound is more difficult to learn, CAH considers phonemes and allophones. PAM-L2, L2LP and SLM consider both phonetic and phonological properties. PAM-L2 also considers the articulatory gestures of sounds between two languages. However, the pitfall of PAM-L2 and SLM is that they quantify the characteristics of L2 sounds to justify whether L1 and L2 sounds produced by native speakers are similar to one another, resulting in difficulty in measuring L2 perception objectively (Levy, 2009b). PAM-L2 and L2LP are similar in that they focus on L2 sound perception by investigating L2 sound contrasts. In terms of the type of learners, PAM-L2 focuses on L2 learners with a good amount of prior L2 use, which is similar to SLM, whereas the target of CAH and L2LP is L2 learners in general. A summary of all models is presented in Table 1.

Table 1. Summary of models of L2 speech learning

Model	Aim	Focus	Aspects of considered in the comparison of L1 & L2	Target group
CAH	To account for L2 learning.	production and perception	phoneme & allophone	L2 learners
PAM-L2	To account for perception of non-native sounds by L2 listeners in L2 natural settings.	perception	phoneme, phonetic properties, articulatory gestures	L2 learners with specific purposes of L2 use in natural language setting
SLM	To explain changes across life span in L2 speech learning.	perception with link to production	phonetic and phonological properties	advanced L2 learners and bilinguals
L2LP	To account for L2 sound perception at all stages of learning.	perception	phonetic and phonological properties	L2 learners

None of the models specifically focuses on L2 learners who have mainly learned the L2 in the L1 country, i.e. English as a foreign language (EFL), not second language (ESL). The learning contexts of a naturalistic L2 immersion setting (ESL) and a classroom setting (EFL) are likely to result in different impacts on L2 learning.

For example, the English VOT production of Catalan-Spanish speakers with English experience in a study-abroad context is more native-like than that of L2 speakers with regular formal instruction (Mora, 2008), reflecting differences in input for L2 learning in a naturalistic setting vs. L2 learning in a classroom setting.

Regarding researchers focusing on L2 learners in their home country, Shahidi (2010) studied the phonetic properties and perception of Malay English as produced by adult Malay English speakers who learned English in an EFL context. This study set out to investigate /p, b, t, d, k g, s, z, i, ɪ/. All sounds, except /ɪ/ which only occurs in English, exist in both Malay and English sound systems. However, the voiceless stops in Malay are always unaspirated in all positions (initial, medial, final) whereas in English, they are unaspirated when preceded by /s/. For obstruent production, acoustic evidence showed no significant differences in Malay and Malay English production confirming the influence of L1 despite that the fact that learners were found to be able to perceive phonetic differences between some contrasts, such as initial /p/ of Malay and English. As perceptual ability did not always help L2 production, this is contradictory to PAM. /i/-/ɪ/ contrast production showed a distinction in Malay English, but both sounds were realised in a form which was different from both Malay and native speakers of English, suggesting a non-native pronunciation. This suggests that both similar and different sounds might be difficult to produce, which is contrastive to both SLM and PAM. The finding of /i/-/ɪ/ contrast production led Shahidi (2010) to conclude that current L2 models do not cater for contexts where L2 learners use L2 in an EFL environment.

Almbark (2012) developed the Foreign Language Model, which accounts for English vowel production and the perception of learners who are in their home country and study L2 as a foreign language in the classroom context for many years. These L2 learners have a phonetic perception similar to that of naïve listeners, but they can learn L2 sounds if phonetic differences between the L1 and L2 sound are noticeable or if they are given direct instruction. In this model, speech perception precedes speech production. Although this model does not include other factors and – similar to PAM-L2 – its focus is on testing sound contrasts rather than individual sounds, the target learners of this model are more similar to the L2 learners in this study in that both groups had extensive background of learning English as EFL, receiving input mainly from instructors who shared linguistic backgrounds to them which might greatly affect their L2 production to be less target-like and/or native-like. Non-native input in L2 learning might result in negative effects on L2 learners (Young-Scholten, 1995). Although L2 sound production might be improved via exposure to native input later, the 'fossilisation ceiling' (Akita, 2001, p. 187) might block L2 learners from native-like production.

For target-like analyses, two methods are used: a) impressionistic analysis, in which the author, who is a trained phonetician and has shared linguistic background with the L2 learners, will analyse the L2 sound production; and b) a sound identification task, in which target-likeness is analysed through a group of native speakers of L2. For native-like analyses, two other methods are used: a) an accent rating task, in which realisations that are deemed target-like based on an impressionistic analysis will be rated for their degree of accentedness as perceived by a group of native speakers of the L2; and b) an acoustic analysis, in which realisations that are deemed target-like based on an impressionistic analysis will be acoustically investigated. As PAM-L2 and L2LP focus on the perception of non-native sound contrasts, it might not be appropriate to base predictions on these models because hypotheses for this study are based on individual sound tokens rather than sound contrasts. However these two models are useful in accounting for the findings in terms of L1 influence on L2 sound learning. Hypotheses are generated based on the other two models – CAH and SLM. For CAH, hypotheses are based on judgements of target-likeness whereas for SLM, hypotheses are based on judgements and analyses of native-likeness.

Starting with predictions made by the CAH, the area of difficulty depends on whether an L2 sound occurs in the L1 phonological system – that L2 sound is difficult when that L2 sound does not exist in the L1 sound system. Thus, the area of difficulty is only based on the phonological systems of L1 and L2, making the model useful for pointing out L2 sounds that are potentially problematic for L2 Thai learners of English. Within this vein, shared fricatives are predicted to be easy to produce whereas non-shared fricatives are predicted to be difficult. Hence, in the impressionistic study, the percentage of realisations of shared fricatives that are deemed target-like as produced by the L2 Thai learners will be high and the corresponding scores should not differ from those of the native speakers of the L2. For non-shared fricatives, the percentage of realisations that are deemed target-like as produced by the L2 Thai learners will be low and the corresponding scores will be lower than those of native speakers of the L2. Similarly, for sound identification task, it is expected that the percentage of correct identification of shared fricatives as produced by the L2 Thai learners will be high. For non-shared fricatives, the percentage of correct identification of L2 Thai learners' production will be low. For the accent rating task and acoustic analysis, predictions based on the CAH cannot be generated as it does not focus on native-likeness.

For SLM, regarding the sociolinguistic study, the model only focuses on age of arrival (AOA), which is not of interest in this study as all the subjects arrived in the UK when they were adults. In terms of the linguistic investigation, according to SLM, L2 learners will produce similar sounds (shared fricatives) in a less-native-like manner as compared to new sounds (non-shared fricatives) and thus the hypotheses are in the opposite direction to those in CAH. The SLM cannot generate hypotheses for target-like analyses as target-likeness of L2 sound production is not the aim of the SLM (Daland *et al.*, 2014).

For accent rating task, hypotheses from SLM are that the shared fricatives will be difficult to produce; hence it is expected that the score of native-likeness of L2 sound will be lower than that of L1 sounds produced by native speakers of L2 whereas for non-shared fricatives, they will be easy to produce; hence it is expected that the score of native-likeness of L2 sound will not be different from the L1 sounds produced by native speakers of L2.

For acoustic analysis, hypotheses based on SLM are that the phonetic properties of shared sounds produced by L2 learners will be different from those produced by native speakers of L2; hence shared sounds are difficult to produce. For non-shared sounds, on the other hand, the phonetic properties as produced by L2 learners will be more similar to those produced by native speakers of L2; hence non-shared sounds are easier to produce. The predictions for both models are presented in Table 2. The discussion regarding the extent to which the predictions from the models are confirmed will be included in Chapter Seven.

Table 2. Summary of model predictions

Task	Sound	CAH	SLM
Impressionistic	shared sounds	easy (the target-likeness scores of the L2 production is high and not different from L1 production by native speakers of L2)	N/A
	non-shared sounds	difficult (the target-likeness scores of the L2 production is low and lower from L1 production by native speakers of L2)	N/A
Sound identification	shared sounds	easy (the correct identification scores of the L2 production is high)	N/A
	non-shared sounds	difficult (the correct identification scores of the L2 production is low)	N/A
Accent rating	shared sounds	N/A	difficult (the native-likeness scores of the L2 production is lower than that of the L1 production by native speakers of L2)
	non-shared sounds	N/A	easy (the native-likeness scores of the L2 production is closer to that of the L1 production by native speakers of L2)
Acoustic	shared sounds	N/A	difficult (the acoustic characteristics of L2 production are different from those of L1 production by native speakers of L2)
	non-shared sounds	N/A	easy (the acoustic characteristics of L2 production are closer to those of L1 production by native speakers of L2)

2.3 Factors in L2 acquisition

In addition to differences between the L1 and L2 phonetic and phonological inventories, other factors tend to influence L2 pronunciation (Hanulíková and Weber, 2010). In order to further explore the nature of this particular ESL context and its potential influence on learners' linguistic behaviour, many factors including motivation, length of residence (LOR), L2 English exposure, gender, word frequency and vowel context will be investigated for their relationship with L2 target-like production. Factors in this study are divided into two main categories: internal and external (Tagliamonte, 2013). External factors here refer to non-linguistic aspects, e.g. motivation, length of residence (LOR), exposure to English, and so on. Internal factors, on the other hand, include word frequency and vowel context. The details of each factor are addressed in turn.

2.3.1 External factors

Length of residence (LOR)

LOR in L2 learning refers to the duration spent in a country in which the target language is mainly used (Piske *et al.*, 2001). Many studies have provided evidence of a positive correlation between LOR and the degree of native-like production (e.g. Asher and García, 1969; Purcell and Suter, 1980; Flege *et al.*, 1995b; Drummond, 2010). For instance, Asher and García (1969) investigated the degree of foreign accentedness of Cuban immigrants in the US. The authors found that half of the Cuban subjects living in the US for 5–8 years had a near-native accent, whereas only 15% of subjects living in the US for four years or fewer did, supporting the notion of the importance of length of time in the L2 community. Another study by Drummond (2010) focused on the learning of the Manchester dialect by Polish speakers and found an LOR of 2–72 months to be correlated positively with all four local features: STRUT vowel, glottal realisation of /t/, alveolar realisation of (ing) and h-dropping.

Some studies have found that the effect of LOR was not always definitive (e.g. Ekstrand, 1975; Oyama, 1976; Tahta *et al.*, 1981; Thompson, 1991). For example, Ekstrand (1975) investigated the effect of LOR in relation to many aspects of language proficiency. Over 2,000 immigrant pupils in Sweden from various ethnic backgrounds were tested on many facets and by many means: pronunciation, dictation, listening comprehension, reading comprehension, free oral production and free written production. Whereas a positive correlation between LOR and free oral production was found, most other language variables had a weak correlation with LOR. According to the author, this might be due to the small number of subjects with an LOR longer than two years and the slow process of language learning. This opinion is supported by Piske *et al.* (2001), who found that the LOR effect tends to be found when the range of LOR in the L2 learner group is longer rather than shorter. It should further be noted that the length of LOR which can be considered comparable to a naturalistic L2 setting has not yet been determined as shown in a study of L2 perception by L2 learners with an LOR of around three years in which the participants' ability to discriminate L2 contrasts was still poor (Guion *et al.*, 2000). On the other hand, Best and Tyler (2007) suggest that the minimum number of years of living in an L2 country necessary for people to become experienced L2 learners is relatively low, perhaps 6–12 months. Hence, it seems that the effect of LOR should be treated with caution and its effect is best seen when long LORs are looked at. However, there are no firm conclusions regarding the appropriate duration of residence in the L2 country. It is not always the case that longer LOR shows a positive correlation with a higher level of linguistic ability. It might be that in L2 learning, LOR is also related to other factors, such as L2 exposure, which is discussed in the next sub-section.

L2 exposure

L2 exposure is different from LOR in that L2 exposure refers to the amount of L2 use in the L2 country, whereas the LOR refers to the duration of residence of the L2 learners in the country in which the L2 is used. The amount of exposure to the L2 also affects the level of target-like production. Stevens (2011) explored the influence of various external factors on Spanish vowel production by American English speakers. The results of multivariate analyses showed that the length of exposure to Spanish television was one of the factors affecting Spanish vowel production by American English speakers who had studied abroad; in other words, more frequent watching of Spanish television led to significantly more native-like pronunciation. Similarly, Flege *et al.* (2006) investigated the degree of foreign accentedness in English sentences produced by Korean children and adults who had migrated to the US or Canada. The findings showed a correlation between sentence rating scores and the overall amount of English exposure in both groups: the more the learners were exposed to the target language, the less foreign their accents became.

On the other hand, some findings (e.g. Purcell and Suter, 1980; Flege and Fletcher, 1992; Elliott, 1995) showed that there is no correlation between the amount of L2 exposure and the success rate of L2 production. For example, Flege and Fletcher (1992) investigated if there was a correlation with the degree of perceived foreignness in accent and L2 exposure, which was calculated based on self-reported daily English use. The findings showed that there was no significant effect of L2 exposure on the degree of foreign accentedness. It is possible that L2 exposure relates to the combination of many skills of using L2 and when subjects reported that they used a high proportion of L2, it did not necessarily mean they often spoke. It might mean that they did some other activities, such as reading or writing in L2. The other reason might be due to the fact that the L2 exposure is actually correlated with many other factors. In their investigation, the authors tried to find a correlation between L2 exposure and other factors (age, education, sex, AOA, LOR); however, it might be that LOR is correlated with more than one factor, which is difficult to investigate using statistics based on correlations.

Gender of speaker

In L2 learning, most studies have shown that females generally have higher ability in language learning (e.g. Asher and García, 1969; Piske *et al.*, 2001; Díaz-Campos, 2004; Major, 2004). For example, an investigation of speech samples of L2 Spanish consonant learning by American English speakers showed that female students have more native-like pronunciation than male students (Díaz-Campos, 2004). Asher and García (1969), who carried out an investigation of the degree of foreign accentedness in Cuban immigrants in the US aged seven to 19, found that 75% of girls who arrived in the US between the ages of one to six had near-native speech production compared to 33% of the boys. With an AOA of seven to 12 years old, 50% of girls had near-native pronunciation in contrast to 28% of the boys. Although most of the children aged 13 to 19 years when they migrated to the UK had strong foreign accents, the study findings still give support to the notion that girls generally outperform boys in L2 speech production.

The results of studies on linguistic ability which favour females over males seem to give importance to gender with no relation to other factors. However, some other researchers have pointed out that L2 female learners do not always outperform their counterparts in speech learning (e.g. Purcell and Suter, 1980; Flege *et al.*, 1995b). In the study by Flege *et al.* (1995b), the English speech of native Italian speakers in Canada was rated for its degree of foreign accentedness, with lower scores indicating a stronger foreign accent. It was found that the degree of foreign accentedness was related to AOL, in that L2 female speakers with an average AOL of 9.6 years had higher scores than males, whereas females with an average AOL of 21.5 years had lower scores than male speakers, suggesting that gender is also correlated with AOL.

The trend for girls usually outperforming boys linguistically is claimed to be due to social factors, such as family influences, female bias in the topics in school courses and there being fewer male language teachers than female teachers (Moys, 1996; Callaghan, 1998). Females are also more oriented to norms of behaviour and therefore to the standard variety of a language. Hence, the issue of gender seems to also correlate with other factors which create different L2 learning environment for both genders.

Motivation

Motivation has a strong influence on the learning of L2 (Hashimoto, 2002). Many research studies have investigated the relationship between L2 learning and motivation. Early work by Gardner and Lambert (1959) sheds light on the issue of motivation in second language learning. The researchers believed that language learning relates to social and psychological dimensions which affect motivation; these relate to the extent to which learners ‘identify with members of another ethnolinguistic group and […] take on very subtle aspects of their behaviour, including their distinctive style of speech and their language’ (Gardner and Lambert, 1972, p. 135). Gardner and Lambert proposed two types of motivation which can contribute to mastering a second language: i) integrativeness and ii) instrumental orientation. The first term refers to the purpose of learning a language being to ‘come closer to the other language community’ (Gardner, 2001, p. 5). Learners with integrativeness have a desire to learn the language and positive attitudes towards the language and people of that community. The latter term signifies the aim of learning a language for future gain.

According to Gardner (2001), integrative motivation is a variant that occurs when the learner has a certain goal to attain. The goal of L2 learners is assumed to be the attainment of near-native-like language proficiency and identification with the L2 community. Gardner proposed a socio-educational model of second language learning in which integrative motivation has three attributes: integrativeness (real interest in learning the language to come closer to the target language community), motivation (a driving force in any event) and attitudes toward the learning situation (attitudes toward any attributes of the events of language learning). In addition, the level of language attainment might also be due to other factors, such as language anxiety and self-confidence. The main points of Gardner’s socio-educational model of second language learning are usually measured through the Attitude/Motivation Test Battery (AMTB) (e.g. Gardner and MacIntyre, 1991; Brown *et al.*, 2001; Masgoret *et al.*, 2001; Masgoret and Gardner, 2003; Bernaus *et al.*, 2004; Drummond, 2010).

However, the popularity of this model has declined due to the ambiguity of its terminology. Dörnyei (2005) pointed out two main problems: i) the term ‘integrative’ appears in three different forms (integrative orientation, integrativeness, and integrative motive/motivation); ii) under the topic of ‘integrative motivation’ there is a subtopic called ‘motivation’. These two issues lead to difficulty in clarifying a boundary between each type of motivation. Following criticism of Gardner’s model, Dörnyei (2005) proposed a new motivational framework, the ‘L2 Motivational Self System’. This model encompasses three aspects: i) the ideal L2 self, which is the hope of becoming professionally successful in the L2; ii) ought-to L2 self, which is an effort in language learning to avoid negative outcome; iii) L2 learning experience, which is related to learning factors (e.g. teacher, peer group, curriculum). Among these three aspects of the L2 Motivational Self System, the ideal L2 self is often found to be correlated with the ought-to L2 self (e.g. Ryan, 2008; Papi, 2010; Kormos *et al.*, 2011). According to Ryan (2008), they both have a focus on the learner’s future ambitions and responsibilities as learners of language; however, the ideal

L2 self is a label for the affective dimension, motivating the learner to learn a language, whereas the ought-to L2 self covers pragmatic aspects to a greater extent. The correlation found between these two might be due to the transitional period of the age ranges of participants, for example the transition from teenagers to adults, meaning that the learners might not have developed fully the distinction between these two selves (Papi, 2010). Alternatively, it could be due to the collective culture in the learner's society, resulting in a social standard fostering the ideal L2 self in learners (Fukuyama, 1992). This latest framework is different from Gardner's model in that it includes 'images and senses, approximating what people actually experience when they are engaged in motivated or goal-directed behaviour' (Dörnyei, 2009, p. 15). According to Ushioda (2009), these possible selves are very powerful in terms of allowing L2 learners to visualise themselves in the future as highly proficient language users in connection with their present selves. This framework supported to be cross-linguistically practical in terms of relating learners' identity and other environmental factors to other measurement variables (Al-Shehri, 2009; Csizér and Kormos, 2009; Papi, 2010). It can better explain the link between cognitive motivational concepts and motivational psychology than Gardner's model (Dörnyei, 2009).

As the crucial aspect for language learners to be successful in the long run is their view of themselves in the future (Dörnyei, 2005), most previous research has shown the importance of the ideal L2 self in influencing learning behaviour, rather than the other two components (e.g. Ryan, 2009; Taguchi *et al.*, 2009; Csizér and Lukács, 2010). For example, Csizér and Lukács (2010) explored the motivational and attitudinal dispositions of Hungarian language learners with English and German as their foreign languages. They used a five-point Likert-type questionnaire covering many dimensions of motivation such as the ideal L2 self and the ought-to L2 self, English/German use, anxiety and cultural interest. Their results showed the ideal L2 self to be the most significant factor in motivating the learning behaviour for English and German.

Apart from these three main components, other motivational factors are often added to investigate levels of motivation in language learning. One of the most well-known variables is L2 anxiety, which refers to mental components and the feelings of the individual, such as worry and apprehension accompanied by activation or arousal of the autonomic nervous system (Spielberger, 1983). When learning a foreign language, learners are reported to experience feelings of panic when speaking with no preparation, to be nervous and confused when speaking in language class and to be very self-conscious when using a foreign language in front of other students (Horwitz *et al.*, 1991). Many studies have shown that anxiety is related negatively to language performance (e.g. MacIntyre and Gardner, 1991; Kitano, 2001; Alemi *et al.*, 2011; Zhang, 2013).

To summarise, seven external factors are of interest in this study: LOR, L2 exposure, gender, ideal L2 self, ought-to L2 self, L2 experience and L2 anxiety. It is hypothesised that LOR, L2 exposure, ideal L2 self, ought-to L2 self and L2 experience will be correlated positively with target-like L2 production. L2 anxiety is expected to be correlated negatively with L2 production. In terms of gender, being female is expected to be related to target-like L2 production.

2.3.2 Internal factors

Vowel context

The influence of one sound on another is likely to be due to a coarticulation effect, which refers to 'overlapping movements in the production of neighbouring or near-neighbouring phonetic segments' (Nittrouer and Studdert-Kennedy, 1986, p. 74). Many studies have shown that L2 learners have more difficulty in acquiring a target sound in some vowel contexts than other vowel contexts (e.g. Schmidt, 1996; Hardison, 2003). For example, an investigation of the learning of American English /ɹ/ and /l/ by Korean and Japanese learners (Hardison, 2003) showed that the perceptual scores for these two sounds were lowest with rounded vowels for both groups of learners; this suggests that a coarticulatory effect of lip rounding on these two target sounds results in difficulty in their discrimination. Work by Schmidt (1996) also confirms that the vowel context affects the perception of L2 sounds by L2 learners. In his study, 20 Korean participants listened to 22 English word-initial consonant sounds in three vowel contexts and judged the level of similarity between English consonants and Korean consonants on a scale of 1 to 5. The results revealed that for English /m, n, j, p, t, k, h/, the rating scores were higher in the /a, i/ contexts and lower in the /u/ context. These studies show that the lip rounding of the vowels affects target-like consonant learning.

Word frequency

In producing words, both phonological and semantic knowledge are used. Word knowledge is related to word frequency, i.e. language learners are thought to learn high-frequency words before low-frequency words (Vermeer, 2001). High frequency helps speakers to produce the words, especially when they are in irregular form (Ellis, 2002). In L2 English speech production, L2 learners might find it challenging to pronounce words they rarely experience or have never experienced before.

Measurements of word frequency are normally estimated in two ways: i) asking subjects how familiar they are with the words tested, sometimes called 'word familiarity' (e.g., Baker and Trofimovich, 2005; Imai *et al.*, 2005), or ii) obtaining the frequency from published sources, such as a speech corpus or dictionary (e.g. Imai *et al.*, 2005; Drummond, 2010). The first method has the advantage of obtaining an estimate of frequency directly from the subjects; however, it contains some degree of subjectivity, which might affect the reliability of the data. Although frequency in a corpus might not reflect the actual exposure of L2 learners, corpus-based occurrences can be used based on the assumption that if word frequency affects L2 speech production, the subjects should articulate more target-like sounds in words in higher frequency words than in lower frequency words (Baker and Trofimovich, 2005).

Word frequency has been shown to have an effect on L2 speech learning (e.g. Akamatsu, 2002; Levi *et al.*, 2007; Drummond, 2010). For example, lexical frequency was found to have a significant effect on English Manchester STRUT vowel production by Polish speakers in a negative way (Drummond, 2010). The perception of foreign accentedness also depends on lexical frequency. Levi *et al.* (2007) investigated this effect by asking German learners of English and American English speakers to articulate real English words with three different ranges of frequency: high, medium and low. Then, 60 native English listeners rated the foreign accentedness of the words they heard. The results showed that words of lower frequency were rated as more accented (more foreign) than words of higher frequency. The authors concluded as listeners have fewer exemplars for low-frequency words in their memory to match than high-frequency words, they sound more accented in low-frequency words.

Similarly, in a work by Akamatsu (2002), reaction time in word naming was tested with Chinese, Japanese and Persian learners of English to investigate the effect of word frequency and regularity. The results showed that regularity was not a problem in high-frequency words (either regular or irregular); in other words, learners could produce these words with no significant difference in reaction time. However, in low-frequency words, learners took longer to recognise irregular words compared to regular words. Akamatsu's (2002) study supports the idea that word frequency is interrelated with word knowledge. Word knowledge includes orthographic knowledge, which refers to understanding of the conventions of the writing system of the language (Treiman and Cassar, 1997). Hence, in the case that a word is spelled with unconventional orthography, this is likely to hinder L2 learners from decoding the word. When L2 learners have considerable experience of the spelling of the word, they tend to be able to produce it accurately. From these results, frequency will be taken into account in this study, and it is expected that higher frequency words will facilitate target-like L2 production in contrast to lower frequency words.

2.4 Acoustic characteristics of fricatives

In addition to looking at the relationship between various factors and target-like L2 fricative production, this study also investigates L2 fricative production through acoustic analysis to find out the phonetic properties of realisations of L2 English fricatives that are deemed target-like and compared these to their native English and native Thai (only for shared fricatives) counterparts. The investigation of phonetic properties of sounds will provide us in-depth phonetics characteristics that are beyond human awareness.

A fricative is a speech sound that is made by forcing the air through two articulators that are partially constricted causing audible friction (Stevens, 1971; Shadle, 1990). As with other sound categories, the fricative is sensitive to context. It varies in its acoustic properties according to vowel context, gender and language group. Understanding the acoustic characteristics of fricatives helps us become aware of the influence of these factors. An acoustic approach to the study of fricatives also enhances objectivity in the data analysis, as human perception usually shows variability in transcription, tending to be affected by many factors such as individual perception and linguistic background (Li *et al.*, 2009). A review of the acoustic characteristics of fricatives is presented here.

Many acoustic measurements are required to measure the characteristics of fricatives, as no single acoustic cue can provide a definite representation of the identity of a fricative (Jongman *et al.*, 2000). Studies on the acoustics of fricatives have shown that both ‘static’ (measuring one location in the speech sound) and ‘dynamic’ properties (measuring acoustic changes between target fricatives and adjacent sounds) (Jongman *et al.*, 2000) are useful in distinguishing fricatives.

Several types of acoustic measurement have been shown to be useful in distinguishing fricatives in terms of places of articulation, sibilance and voicing. These measurements include: overall spectral shape and spectral peak location (Strevens, 1960; Behrens and Blumstein, 1988; Jongman *et al.*, 2000), onset F2 frequency (McGowan and Nittrouer, 1988; Nittrouer *et al.*, 1989; Jongman *et al.*, 2000), normalised (Behrens and Blumstein, 1988; Jongman *et al.*, 2000) and relative amplitude (Hedrick and Ohde, 1993; Jongman *et al.*, 2000), absolute (Behrens and Blumstein, 1988; Jongman *et al.*, 2000) and normalised duration (Jongman *et al.*, 2000), linear regression lines fitted to the spectrum (Evers *et al.*, 1998; Jesus and Shadle, 2002), and four spectral moments (Forrest *et al.*, 1988; Jongman *et al.*, 2000; Nissen and Fox, 2005), among others.

The following seven acoustic parameters are the most widely used in the literature: four spectral moments (the centroid, SD, skewness and kurtosis), peak location, normalised amplitude and onset F2 frequency. First, the acoustic measurements most widely used are spectral moments (e.g. Forrest *et al.*, 1988; Nittrouer, 1995; Jongman *et al.*, 2000; Li *et al.*, 2009), which reflect the shape and ‘peakiness’ of the spectrum of fricatives. Figure 1 shows the spectrums of fricatives spoken by a British female speaker. These fricatives in four places of articulation /f, θ, s, ʃ/ have different spectral shapes with /f/ showing the highest peak (15221 Hz), followed by /θ/ (11749 Hz), /s/ (11011 Hz) and /ʃ/ (6783 Hz), respectively.[7] From the figure, besides the peaks of /f/ and /θ/ are flatter, their spectral shapes are also flatter as they are non-sibilant. For sibilant, i.e. /s, ʃ/, their

[7] Please note that the frequency values obtained here maybe different from my study as I am looking at frequencies up to 16 kHz.

spectrums are more compact and their major peaks are in the mid-high frequencies.

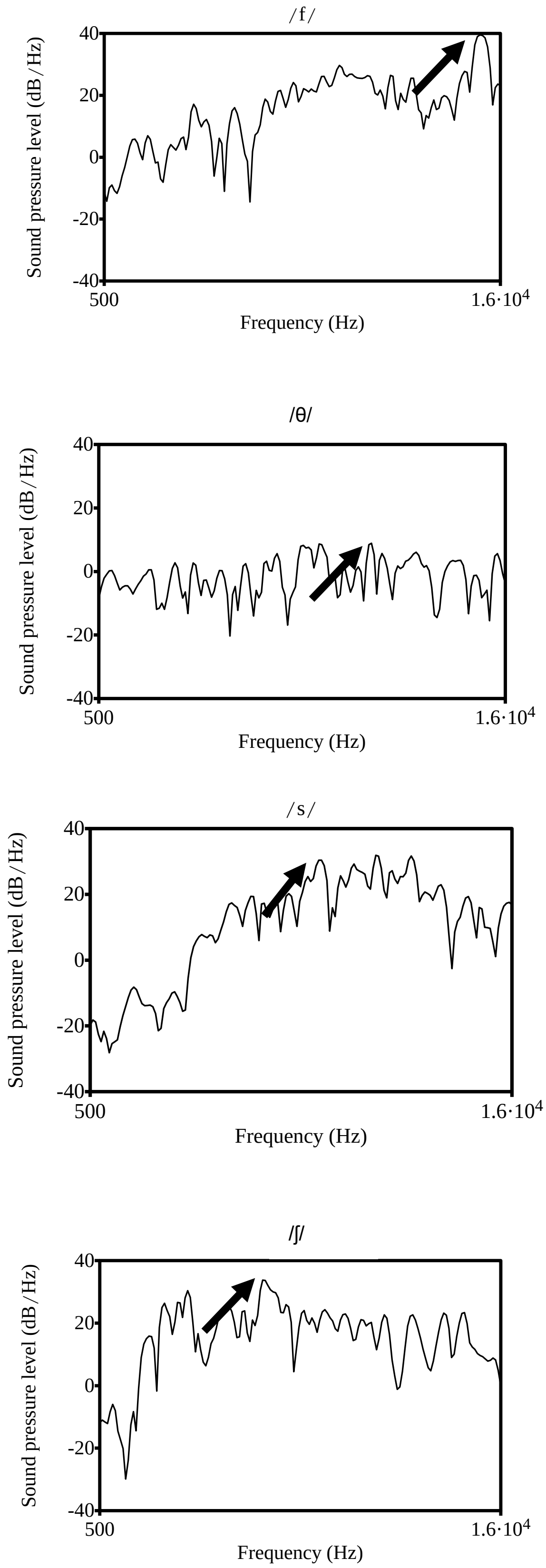

Figure 1. Spectrums of fricatives according to place of articulation: /f/ from ‘fever’, /θ/ from ‘thief’, /s/ from ‘seat’ and /ʃ/ from ‘she’ produced by a British English female speaker

The first spectral moment, which is referred to as ‘M1’, is that of the central gravity or the centroid. It indicates an averaged energy concentration of the fricative spectrum (Jongman *et al.*, 2000). The averaged energy concentration refers to the mean of all peaks in the spectrum. Even though there is no reported significant difference between the labiodental and dental fricatives /f, θ/, the centroid measure differentiates between these and other fricatives, i.e. it distinguishes /f, θ/ from /s/ and /ʃ/ (Nissen and Fox, 2005). This M1 is also supported to distinguish /s/ from /ʃ/ – with the frequency range of /ʃ/ being lower than for /s/ (Strevens, 1960; Nittrouer *et al.*, 1988; Nittrouer *et al.*, 1989; Nittrouer, 1995; Evers *et al.*, 1998; Jongman *et al.*, 2000). In terms of vowel context, this measurement is higher in the /i/ than the /u/ context (Nittrouer *et al.*, 1988; Nittrouer, 1995). According to Li (2008), this measurement should be related negatively to the length of the front cavity, i.e. the more fronted the fricative, the higher M1. Hence, it can be used to indicate roughly where each fricative is produced. M1 has also been found to be indicative of speech effort; in speech with higher effort, a fricative with higher effort should have a higher M1 value (Maniwa *et al.*, 2009).

Second, ‘M2’ is a measure of standard deviation or SD; it provides information on the dispersion of the spectrum from its mean frequency (Fulop, 2011, p. 75) and is the average squared distance from the centroid. The M2 of non-sibilants is generally higher than that of sibilants (Shadle and Mair, 1996; Jongman *et al.*, 2000; Nissen and Fox, 2005). It was found to be useful in distinguishing alveolar /t/ from dental /t/ with higher SD for more fronted /t/ (Stoel-Gammon *et al.*, 1994). In addition, according to Maniwa *et al.* (2009), M2 is also higher in more effortful speech.[8]

Third, ‘M3’ is a measure of skewness; it describes the extent to which a probability distribution is on the left or right of the spectrum and how skewed the distribution is. This is the difference between the frequency range below and above the centroid (Li, 2008). When energy is concentrated in the lower frequency range, the skewness will be positive, whereas when the energy is in the higher frequency range, the skewness will be negative (Jongman *et al.*, 2000). M3 is useful in

[8] This may be different due to the computation: Maniwa et al.’s study (2009) computed the variance, and in this study, the author has computed the standard deviation (as all other studies have done).

differentiating fricatives according to place of articulation, with higher M3 representing a more retracted fricative (Li, 2008). M3 is also higher in more effort speech (Maniwa *et al.*, 2009).

Finally ‘M4’ or ‘kurtosis’ refers to the ‘peakiness’ of the probability distribution, i.e. whether the spectrum is flat or peaky. It provides information on how the shape of the spectrum around the centroid differs from a Gaussian shape. For example, if the kurtosis values are positive, peakiness will be rather high; on the other hand, if they are negative, the spectrum will be flatter. Higher kurtosis is correlated to sibilants (Jongman *et al.*, 2000). In the work of Stoel-Gammon *et al.* (1994), M4 was found to be lower in dental /t/ than alveolar /t/. M4 can also be interpreted in terms of degree of effort, i.e. higher in higher effort speech (Maniwa *et al.*, 2009).

Although spectral moments are good indicators for differentiating alveolar from postalveolar fricatives (Tjaden and Turner, 1997), they are not reliable measurements for distinguishing fricatives according to the four places of articulation (Shadle and Mair, 1996). In addition, given that calculating spectral moment values from a single window location might result in a large error in the spectral estimate (Shadle, 2012) and that fricative noise is random by nature (Fulop, 2011), Shadle (2012) provides descriptions of four averaging measurements of spectral moments: time averaging, ensemble averaging, frequency averaging and multitaper analysis. Many papers on fricative measurements have now shown that even with large errors in the estimates, results are not different from a linguistic point of view regardless of whether the averaging is made or not (Reidy, 2015).

Out of the four methods, the multitaper analysis seems to be the best. Despite the advantages of averaging techniques, the majority of past research studies analysing fricative characteristics by spectral moments have not used these techniques in their analyses (e.g. Strevens, 1960; Nittrouer *et al.*, 1988; Nittrouer, 1995; Jongman *et al.*, 2000; Nissen and Fox, 2005).

Another widely used acoustic measurement is spectral peak location, which is the highest peak in the fricative noise. It can distinguish American English fricatives according to place of articulation, as the value of the peak location is higher when the place of articulation moves forward – Jongman *et al.* (2000), the peak locations for /f, v/ were 7733 Hz, for /θ, ð/ 7470 Hz, for /s, z/ 6839 Hz and for /ʃ, ʒ/ 3820 Hz. The usefulness of peak location in distinguishing sibilants from non-sibilants has been shown in many studies (e.g. Hughes and Halle, 1956; Strevens, 1960; Behrens and Blumstein, 1988), with a higher value reported for sibilants than for non-sibilants. In terms of degree of effort, peak location should be higher in more effort speech (Maniwa *et al.*, 2009).

The next acoustic measurement is the onset F2 frequency. This is the F2 frequency at the transition between the targeted fricative and the following vowel (Jongman *et al.*, 2000). The onset F2 frequency has been used to measure fricatives in many studies (e.g., Nittrouer, 1995; Jongman *et al.*, 2000; Li *et al.*, 2009); it shows a correlation with fricative place of articulation (higher value as the place of articulation moves further back), with no significant difference between dental and alveolar fricatives (Jongman *et al.*, 2000). However, the F2 onset value increases in high vowel contexts (McGowan and Nittrouer, 1988; Nittrouer *et al.*, 1988; Jongman *et al.*, 2000). It should also be higher in more effort speech (Maniwa *et al.*, 2009).

Finally, normalised amplitude is the difference in amplitude between the target fricative and surrounding vowels (Behrens and Blumstein, 1988). This measurement does not seem to be useful in distinguishing labiodental from dental fricatives; however, if these two fricatives are combined, the higher normalised amplitude represents the sibilants whereas the lower normalised amplitude represents the non-sibilants (Behrens and Blumstein, 1988). In addition, normalised amplitude should be higher in higher effort speech.

The summary of the acoustic properties of fricatives is shown in Table 3.

Table 3. Summary of important acoustic characteristics of fricatives

<table>
<tr><th>Measurement</th><th>Definition</th><th>Interpretation in terms of place of articulation</th><th>Interpretation in terms of sibilance</th><th>Interpretation in terms of degree of effort</th></tr>
<tr><td>Peak location</td><td>The highest peak in the noise</td><td rowspan="3">higher → more forward</td><td rowspan="2">higher → more sibilant</td><td rowspan="7">higher → higher effort</td></tr>
<tr><td>M1</td><td>Simple mean of the spectrum</td></tr>
<tr><td>M2</td><td>Variance of the spectrum</td><td>higher → less sibilant</td></tr>
<tr><td>M3</td><td>How skewed the distribution is</td><td rowspan="2">higher → more retracted</td><td>N/A</td></tr>
<tr><td>M4</td><td>Peakiness of the spectrum</td><td rowspan="2">higher → more sibilant</td></tr>
<tr><td>Normalised amplitude</td><td>Degree of change in sound pressure</td><td>N/A</td></tr>
<tr><td>Onset F2 frequency</td><td>F2 frequency at the transition of fricative and vowel</td><td>higher → more retracted</td><td>N/A</td></tr>
</table>

NB: These measurements were used in the acoustic analysis presented in Chapter Six

2.5 Fricatives in Thai and English

Looking at the sound systems of English and Thai, there are 24 consonant sounds in English whereas there are only 21 consonant sounds in Thai. Of all the consonant categories, the fricative categories in these two languages exhibit the largest differences as there are nine fricatives in English, /f, v, θ, ð, s, z, ʃ, ʒ, h/, and only three in Thai, /f, s, h/. Whereas all fricatives in English can occur in both word-initial and word-final positions, fricatives in Thai can only occur in word-initial position. As this study only focuses on fricatives in initial position, English fricatives in final position will not be reviewed. The details of Thai and English fricatives in initial position are addressed in turn below.

2.5.1 Thai fricatives[9]

In Thai, according to Table 4, there are three fricatives: labiodental /f/, alveolar /s/ and glottal /h/. It should be noted that the /h/ is considered the voiceless counterpart of the adjoined vowel (Ladefoged, 1982) and it is excluded from this study; hence its description is also excluded from this review.[10] In terms of descriptions of Thai fricatives, Harris (1972) collected Thai speech samples from over 60 Thai lecturers, carrying out an impressionistic analysis of their productions. Thai /f/ is similar to English in that is commonly realised as voiceless labio-dental fricative. Before close front vowels, it can be realised as a voiceless labio-dental velarized fricative [ꬵ]. Generally, the Thai /s/ is a voiceless lamino-alveolar grooved fricative. A small number of speakers pronounce it as a voiceless lamino-dental flat fricative or a voiceless lamino-dental grooved fricative. The pronunciation of /s/ before close front vowels can also be a voiceless denti-alveolar grooved fricative, or a voiceless lamino-alveolar velarized grooved fricative as pronounced by a few speakers. The variation in Thai fricative production is therefore likely to be speaker-dependent and affected by the vowel contexts.

[9] Besides fricatives, Thai also has two affricates /t͡ɕ, t͡ɕʰ/.
[10] The description of the variants of Thai /h/ can be found in Harris (1972).

Table 4. The Thai phonological system (Tingsabadh and Abramson, 1993)

	Bilabial	Labio-dental	Alveolar	Post-alveolar	Palatal	Velar	Glottal
Plosive	p pʰ b		t tʰ d			k kʰ	ʔ
Nasal	m		n			ŋ	
Fricative		f	s				h
Affricate				t͡ɕ t͡ɕʰ			
Trill				r			
Approximant					j	w	
Lateral Approximant				l			

As acoustic analysis is one of the methods used in this study, it is essential to review any previous acoustic work on Thai fricatives to obtain detailed description of the phonetic implementation of fricatives in Thai in order to establish subtle differences between their realisations and any counterparts in English. In terms of acoustic analysis, only one study has been carried out (Roengpitya, 2011) in which the author investigated the acoustic characteristics of Thai and English fricatives as produced by three Thai females. This study looked at various acoustic measures including amplitude, duration, *f*0 and formant frequencies to differentiate fricatives in Thai and English. Thai /f, s/ and English /f, v, θ, ð, s, z, ʃ, ʒ/ were elicited in both citation form and connected speech. Even though the author aimed to examine acoustic characteristics of native Thai and L2 English fricatives, there was no description of how these two groups of fricatives were different from each other. The author only addresses voicing, speech style and fricative position, rather than differences between native Thai and L2 English fricatives. No comprehensive discussion of any of the measures is given or rationale for their use. Furthermore, Roengpitya's (2011) study has some limitations. First, the question of whether there are significant differences between native Thai and L2 English /f, s/ is inconclusive as no statistical analysis was used in this study. Second, as the sample size is relatively small, the results are unlikely to be generalisable. Third, although vowel context influences Thai fricative production (as pointed out by Harris, 1972), Roengpitya's analysis did not control for this.

A comprehensive study of Thai fricatives is still needed; hence, this study aims to examine to what extent these three language groups: native Thai, native English and L2 English are different from one another. The next subsection reviews English fricatives, which will be used as the other reference point for L2 English fricatives by L2 Thai learners.

2.5.2 English fricatives

In English, according to Table 5, all fricatives – except /h/ – have a voicing contrast. As stated in section 1.2, /h/ and /ʒ/ have been excluded from this study and thus seven English fricatives are reviewed here. Starting with /f/ and /v/, both are labiodental fricatives made by pressing the lower lip firmly against the upper teeth, forcing the air to go through them (Aslaksrud and Haarberg, 1967; Carr, 1999). Narayanan *et al.* (1995) conducted a study of American English fricatives using magnetic resonance imaging (MRI), and found that they are produced with a bunched tongue body, a raised tongue dorsum, lowered anterior and posterior and downward pointing tip.

Table 5. The English phonological system (adapted from Chan and Li, 2000)

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

/θ/ and /ð/ are both interdental fricatives made by placing the tip of the tongue close to the upper teeth (Aslaksrud and Haarberg, 1967; Carr, 1999), leading the air to escape from the narrow channel created. The body of the tongue is quite flat. In terms of variants, these two fricatives can be produced as stop-like, i.e. /θ/ and can also be produced as [t] in Scotland (Stuart-Smith, 2004), a dental stop [t̪] in Liverpool (Watson, 2007) and [f] in London (Labov, 1969), such as ‘thing’ as ‘ting’ or ‘fing’, whereas /ð/ can also be pronounced as [d], such as ‘then’ as ‘den’ (Labov, 1969) and as a dental stop [d̪] in Liverpool (Watson, 2007). In addition, the production of [d] for /ð/ is also a possibility in some American varieties, such as Cajun English, a dialect of Southern American English (Dubois and Horvath, 1998). The uses of [f] for /θ/ and [v] for /ð/ are common for other British varieties, such as in Milton Keynes, Reading and Hull (Williams and Kerswill, 1999) and Newcastle (Watt and Milroy, 1999). The realisation of British /θ/ and /ð/ as dental fricatives is common in the London working-class accent (Trudgill, 1988) and other low-status urban varieties (Kerswill, 2003).

/s/ and /z/ are formed at the point between the tongue blade and the alveolar ridge and the tongue tip can either be raised towards the teeth ridge or rest against the lower teeth (Aslaksrud and Haarberg, 1967). /s/ is articulated with a narrow slit and may be followed by a deep groove and pit in the tongue (Strevens, 1960). /s/ and /z/ can be formed either with a tongue tip raised at the alveolar ridge – (the apical region) or with the tongue blade – (the laminal region), so these sounds are said to be speaker-dependent (Narayanan *et al.*, 1995). According to Aslaksrud and Haarberg (1967), differences in articulating these two sounds are that /z/ is made with vocal cord vibration and less breath force; however, Verhoeven *et al.* (2011), whilst not distinguishing their findings according to the position of the fricative, found that Southern British /z/ is normally more devoiced than /v/, which might be because /z/ is made with a smaller oral cavity size between the place or articulation and the glottis, resulting in faster equalisation of the pressure differential between subglottal and supraglottal pressure. Similar to Smith (1997), whole and partial devoicing of /z/ is found to be common in English production; however, English listeners can distinguish /s/ from /z/ despite the /z/ being devoiced (Stevens *et al.*, 1992).

/ʃ/ is made with the raising of the tongue blade towards the hard palate or the alveolar ridge, is more retracted and with a wider air passage than for /s, z/, and the lips are protruded (Aslaksrud and Haarberg, 1967). /ʃ/ is produced with a wider area of turbulence (more grooved than /s/) (Strevens, 1960). The constriction is slit-like and wider than /s, z/ – more laminal rather than apical – and these postalveolar sounds are approximately 5–10 mm away from /s, z/ (Narayanan *et al.*, 1995). Overall, it is common for British speakers to produce voiced fricatives as wholly or as partially devoiced, with either no vibration of the vocal cords or friction not long enough to create the frication noise (Docherty, 1992).

The acoustic characteristics of English fricatives have been investigated in many studies (e.g. Hughes and Halle, 1956; Crystal and House, 1988; Forrest *et al.*, 1988; McGowan and Nittrouer, 1988; Nittrouer *et al.*, 1989; Hedrick and Ohde, 1993; Nittrouer, 1995; Evers *et al.*, 1998; Jongman *et al.*, 2000; Nissen and Fox, 2005; Tagliamonte, 2013). Some of these aspects are reviewed below.

With regard to voicing, voiceless fricatives are usually longer than voiced (Crystal and House, 1988). Moreover, they have higher normalised amplitude and relative amplitude than their voiced counterparts (Forrest *et al.*, 1988; Jongman *et al.*, 2000). The higher value might be because voiceless fricatives have ‘higher volume velocity for the same constriction area’ (Jesus and Shadle, 2002, p. 449) than the voiced counterparts.

In terms of place of articulation, fricatives are usually divided into two main groups, non-sibilants and sibilants, according to their hissing effect. In English, the non-sibilants are /f, v, θ, ð/ and the sibilants are /s, z, ʃ, ʒ/. The acoustic characteristics within and across each group are as follows. The non-sibilants have lower normalised and relative amplitude than sibilants (Hedrick and Ohde, 1993; Nissen and Fox, 2005). Within non-sibilants, many studies have shown that spectral moments cannot distinguish labiodental from dental fricatives well (Forrest *et al.*, 1988; Jongman *et al.*, 2000). However Jongman *et al.* (2000) found that the labiodental fricative has a significantly higher value of peak location but lower onset F2 frequency than the dental fricative.

As for sibilants, Evers *et al.* (1998) investigated the acoustic properties of /s, ʃ/ using the slope of a spectral envelope which was computed from linear regression lines below 2.5 kHz and between 2.5 kHz to 8 kHz and found that the left regression line (low frequency) for /ʃ/ is always steeper than that of /s/, whereas the right regression line (high frequency) for /ʃ/ is either the same or less steep than that of /s/. These two fricatives are also well-distinguished by spectral moments (Hughes and Halle, 1956; Forrest *et al.*, 1988). Generally, the alveolar fricative has higher frequency in spectra than the postalveolar fricative (Hughes and Halle, 1956); hence it is not surprising that the centroid of alveolar fricatives is also higher than that of postalveolar fricatives (Nittrouer *et al.*, 1989; Nittrouer, 1995; Jongman *et al.*, 2000; Tagliamonte, 2013). /ʃ/ was found to be more positively skewed than /s/; hence, the value of the skewness of /ʃ/ is usually higher than /s/, but the value of kurtosis of /ʃ/ is lower than /s/ (Nittrouer, 1995). In addition, /s/ has lower relative amplitudes than /ʃ/ (Hedrick and Ohde, 1993), but /s/ has much a higher value for peak location than /ʃ/ (Jongman *et al.*, 2000). For onset F2 frequency, /s/ has a higher frequency than /ʃ/ (McGowan and Nittrouer, 1988). To summarise, English fricatives also have variants like Thai ones, but the variants of English fricatives tend to fall into another phonemic category, such as the replacing of /θ/ by [t], unlike Thai ones that they are still classed as fricatives of the same place of articulation. Voiced fricatives in British English are commonly produced in a devoiced way. As the acoustic study of fricative characteristics is one of the main aspects of this thesis, the understanding of the properties of fricatives both in native English and native Thai are crucially important.

2.6 Studies of English fricative learning by Thai learners

A number of studies on the learning of English fricatives by Thai learners have been carried out. As this study focuses on fricatives in initial position, the review of the fricatives in this section is only on fricatives in that position. Within this area, only three studies have looked at subjects living in the L2 country. Brière and Chiachanpong (1980) analysed pronunciation errors in the speech of four Thai learners of American English; the authors looked at fricatives occurring in free speech and word lists and based their analyses on the contrastive analysis (henceforth CA) framework, stating that differences in sounds between L1 and L2 will cause difficulty. The CAH is based on CA (Huang, 2002). However CA mainly locates difficulty based on non-existing phonemes rather than predicting sound substitution. For example, CA predicts that American English (AE) /ð/ will be difficult for L2 Thai learners but not what is substituted. When looking at the Thai sound system, this sound might be produced as [d, l, r] because they are all voiced oral alveolar sounds. Hence to facilitate the prediction of sound substitutions, Brière and Chiachanpong also based their predictions of L2 pronunciation patterns on the Chomsky and Halle distinctive feature system (1968). For instance, it was predicted that Thai learners will replace AE /ð/ with [d], as /ð/ and /d/ are obstruents whereas /l/ and /r/ are not. The principle of predictions was that L2 learners would substitute an L2 sound with an L1 sound sharing more distinctive features than other sounds in the L1. However, when these two sounds shared a similar number of features, the predictions of the target sound compared to the L1 sound were based on: i) segment distribution, ii) natural class (such as when L1 and L2 sounds are obstruents), or iii) distributional constraints (for example, English speakers learn /ʒ/ faster than /ŋ/ because /ʒ/ occurs in all positions of the word, whereas /ŋ/ does not occur in initial position).

The predictions regarding fricatives were as follows:

1. /θ/ will be realised as [t]. Although Thai /t/ and /s/ share the same number of features as English /θ/, [t] was predicted to be used in substitution due to its occurrence in the same positions as English /θ/.

2. /ð/ will be realised as [d] because both are obstruents.

3. /ʃ/ and /ʒ/ will be realised as [tʃ] because they share the most features with one another.

4. /v/ will be realised as [f] as these two sounds share the most features.

5. /z/ will be realised as [s] because these two sounds also share the most features.

The findings of Brière and Chiachanpong (1980) showed the following substitutions:

- /θ/ was realised as [ð, t]
- /ð/ was realised as [d, n, θ, ʔ]
- /ʃ/ was realised as [t͡ʃ, s]
- /ʒ/ was realised as [z]
- /v/ was realised as [ʋ]
- /z/ was realised as [s]

The /f/ and /s/ in initial position were not investigated as they occur in both Thai and English. The study found that CA accounted for 62% of the errors, which was significantly different from the 38% of errors not predicted by CA. This is the percentage of occurrences calculated from the number of errors divided by the number of occurrences for each sound. It should be noted that this study was an impressionistic study and small scale, with only four participants (two males and two females). Hence, it is important to explore L2 production using a combination of acoustic analysis and increase the number of subjects to be able to generalise the results.

Burkardt (2008) undertook an analysis of errors made by eight Thai speakers in the US on English interdental fricatives in wordlist and passage reading tasks. The results showed that in initial position, /θ/ was mostly realised as target-like and was realised as [t, ð, f, deletion, d, v], whereas /ð/ was mostly replaced by [d] and there were fewer target-like realisations, suggesting that /ð/ in initial position was more difficult than /θ/ for the Thai speakers. The number of errors of these two sounds varied between speakers, signifying that there might be some other factors influencing their voiced interdental fricative production. It should be noted that this study was also small scale, with few subjects, and focused only on two fricatives without controlling vowel contexts. The author also noted that as the subjects were living in the US, it might not be possible to generalise the results to Thai learners of English in other contexts.

Richards (1966) provided a study of English pronunciation by 15 Thai subjects in New Zealand. The results showed that Thai learners realised /v/ as [w]; /θ/ as [t] or [s]; /ð/ as [d]; /z/ as [s] and /ʃ/ as [tɕʰ]. The cause of difficulty was, according to Richards (1966), the discrepancy between L1 and L2. The limitation of these three studies is that their findings were based only on impressionistic study.

Four other studies have been conducted with Thai subjects living in Thailand. Chunsuvimol and Ronakiat carried out two studies on English /v/ (Chunsuvimol and Ronakiat, 2000; Chunsuvimol and Ronakiat, 2001) and one study on English /f/ production by Thai learners (Chunsuvimol and Ronakiat, 2000). In both studies, two main factors were independent variables: speech style and fricative position. The speech samples were produced by 21 female English major students at university: second-year, third-year and fourth-year Thai speakers (seven participants for each year of study). The authors found that Thai learners had no difficulty pronouncing /f/ in initial position due to the similarity of /f/ in the two languages and its occurrence in initial position in Thai (Chunsuvimol and Ronakiat, 2000). Furthermore, both studies revealed that /v/ was produced as [v], [f], and [w]. It is interesting that the fourth-year students had lower target-like /v/ in all speech styles than the third-year students. The authors found that some third-year students had lived in the L2 country prior to university, had been to Western-run schools and had taken specialised courses with native speakers on pronunciation. However, their study provided no statistical results on the weight of the effect of length of L2 exposure compared to other factors relating to L2 learners.

The only study on English fricative perception by Thai learners was carried out by Pansottee (1992). Her study aimed to investigate L1, L2 and the effect of the interstimulus interval (ISI) on speech perception. The ISI is the period between appearance of the first and second word in a discrimination task of sound pairs and was measured either at 500 ms or 1500 ms. It is related to memory trace that enables listeners to detect differences within phonemic categories (Werker, 1984).

The stimuli were divided into three types:

- phonemic sound pair (P) – both sounds exist in L1 and L2: /f/-/s/
- non-phonemic sound pair (NP) – neither sound exists in L1: /θ/-/ʃ/
- phonemic and Non-phonemic sound pair (PNP) – one sound exists in L1 and L2 and the other exists in L2 only: /f/-/θ/, /f/-/ʃ/, /s/-/θ/ and /s/-/ʃ/

The subjects were children aged six and eight years old. Each age group was divided further into two groups: one exposed only to Thai and the other exposed to both Thai and English. The stimuli were non-sense words with target fricatives followed by /a:/ and produced by a native English speaker. The findings showed that an NP-sound pair was discriminated better than the other two which might be due to large difference in intensity of these two sounds suggesting that physical properties of the sounds drive perception ability. PNP-sound pair was discriminated better than a P-sound pair. The results showed that two pairs, /f/-/ʃ/ and /s/-/θ/, were discriminated better than /f/-/θ/ and /s/-/ʃ/, which was assumed to be due to the degree of energy and intensity, i.e. both /f/ and /θ/ are low in energy and intensity while the other two have high energy and intensity.

This study also revealed that the eight-year-old children were better at discriminating sound contrasts than the six-year-old children suggesting developmental changes in perception. For L2 exposure, only eight-year-old children showed improvement in discrimination sound contrasts, but not six-year-old group. In terms of the ISI effect, the shorter length of duration between sounds yielded better discrimination. However, the speech stimuli in this study were non-sense words which might reflect less actual speech quality of fricative as compared to real words. They were also produced by only one native-speaker; hence, the findings might be due to the influence of the speech of the talker rather than English fricatives in general.

Roengpitya (2011) used acoustic analysis in her study. She explored the acoustic characteristics of L2 English and native Thai fricatives occurring initially, intervocalically and finally, in word lists uttered by three female Thai speakers aged 18-19 years old. Seven acoustic characteristics were measured: i) amplitude at three temporal points (onset, duration, offset), ii) fricative duration, iii) vowel duration, iv) fundamental frequency of voiced fricatives, v) voicing duration (if any), vi) fundamental frequency of vowels, and vii) formant frequencies of the adjacent vowels (onset, mid duration, offset).

The author did not describe the results, but merely showed graphs of the acoustic measurements. The description here is from my own observations. For /f/ in citation form, differences in the amplitude between offset and midpoint and between onset and midpoint were greater in native Thai than in L2 English. In carrier phrases, on the other hand, both differences were smaller in native Thai than in L2 English. For /s/ in citation form, differences in amplitude between onset and midpoint were close to each other in native Thai and L2 English, whereas the difference in amplitude between offset and midpoint of native Thai /s/ was somewhat greater than that of L2 English /s/. In carrier phrases, both differences were smaller in native Thai /s/ than L2 English /s/. In the duration analysis, the durations of native Thai and L2 English /f/ in initial position in citation form and carrier phrases were very close to each other. Whereas the durations of /s/ in initial position in native Thai and L2 English were close to each other, the duration of L2 English /s/ in carrier phrases was slightly higher than that of native Thai /s/.

Roengpitya (2011) pointed out that while many L2 English voiced fricatives were produced as devoiced, the substituted voiceless fricatives had lower dB and $f0$ values at the vowel onset than their voiceless counterparts, implying that the dB and $f0$ values were acoustic cues for L2 voiced fricatives. Most L2 English voiceless fricatives were articulated as voiceless, but so were many of the L2 English voiced fricatives. In the discussion, the author only discussed voicing, speech style and fricative position, rather than differences between native Thai and L2 English fricatives.

The main limitations of her study are as follows: i) no statistical results were used to explore whether native Thai fricatives are different from L2 English fricatives; ii) despite many previous studies confirming the coarticulatory effect of vowel contexts on fricative production, this study only controlled vowel contexts for Thai stimuli – either /a/ or /aa/ – but no detail on the vowel identity in English was provided; hence, it is uncertain whether the findings for L2 English fricatives were the actual values or whether they were due to the influence of vowel context.

In summary, most investigations of L2 English fricatives produced by L2 Thai learners have been impressionistic, with only one working on their acoustic characteristics. The point of impressionistic study is to see the learning of target sounds at the phonemic level, as shown in the above mentioned studies. Regarding investigating sounds at the phonemic level, the accent rating task which is another well-known type of investigation, has not been used in any studies on L2 English fricatives produced by L2 Thai learners. The acoustic measurements provide investigation of fine-grained phonetic details of the target sounds. Even so, this issue still needs further investigation, as mentioned in the review. Moreover, the study of shared fricatives has not been explored thoroughly as only one impressionistic study has been carried out for L2 English /f/ (Chunsuvimol and Ronakiat, 2000) with no comparison made between native English /f/ and native Thai /f/ as produced by native speakers. The summary of previous studies on English fricative learning by Thai learners is shown in Table 6.

Table 6. Findings from previous studies on English fricative learning by Thai learners, summarised according to: author, objective, targeted sound, context of subjects, number of subjects, method of data analysis and variable

Author(s)	Objective	Targeted sound (relevant to this study)	Context of subjects	Number of subjects	Method of data analysis	Variable(s)	Main findings
Brière and Chiachanpong (1980)	Investigated pronunciation errors in US English by Thai learners	English /θ, ð, ʃ, ʒ, d͡ʒ, v, z, r, f, l, s/	Thai subjects in L2 country	4 Thai speakers	Impressionistic	Speech style (free speech vs. word list) and word position	/θ/ as [ð, t] /ð/ as [d̪, n, θ, ʔ] /ʃ/ as [t͡ʃ, s] /ʒ/ as [z] /v/ as [ʋ] /z/ as [s]
Burkardt (2008)	Determined what errors were made by Thai speakers in English interdental fricatives	English /θ, ð/	Thai subjects in L2 country	8 Thai speakers	Impressionistic	Speech style (word list vs. passage reading) and word position	/θ/ as [θ, t] /ð/ as [ð, d]
Chunsuvimol and Ronakiat (2000)	Examined stylistic variation of /f/, /v/ in English by Thai speakers	English /f, v/	Thai subjects in L1 country	21 Thai speakers	Impressionistic	Speech style (free speech vs. word list vs. passage reading), year of students, word position	No difficulty pronouncing /f/ /v/ as [v, f, and w]
Chunsuvimol and Ronakiat (2001)	Investigated stylistic variation of /v/ in the English of Thai speakers	English /v/	Thai subjects in L1 country	21 Thai speakers	Impressionistic	Speech style (free speech vs. word list vs. passage reading), word position	/v/ as [v, f, w]

Author(s)	Objective	Targeted sound (relevant to this study)	Context of subjects	Number of subjects	Method of data analysis	Variable	Main findings
Pansottee (1992)	Explored the perception of English sounds by Thai children	English contrasts: (f-s), (θ-ʃ), (f-θ), (f-ʃ), (s-θ), (s-ʃ)	Thai subjects in L1 country	48 Thai children	Perceptual	Age, experience in English vs. non-experience	The sound pair with phonemes not present in L1 was better discriminated than the sound pair with phonemes that exist in L1 and L2 or the sound pair with one sound that existed in the L1 and the other existed in L2. The sound pair with one sound that existed in the L1 and the other in the L2 was better discriminated than the sound pair with both phonemes existing in the L1 and L2.
Richards (1966)	Observed English production by Thai speakers	English /v, θ, ð, z, ʃ, ʒ/	Thai subjects in L2 country	15 Thai speakers	Impressionistic	(None)	/v/ as [w] /θ/ as [t] or [s] /ð/ as [d] /z/ as [s] /ʃ/ as [tɕʰ]
Roengpitya (2011)	Explored acoustic characteristics of English (L2) and Thai (L1) fricatives	English /f, v, θ, ð, z, s, ʃ/ and Thai /f, s/	Thai subjects in L1 country	3 native Thai speakers	Acoustic and impressionistic	Speech style (citation form vs. word in carrier phrase), word position, voicing	(No results described)

2.7 The EFL situation in Thailand

In Thailand, the start of English use goes back to the reign of Rama III (1824-1851) (Foley, 2005). He considered English essential to deal with British colonial power in other countries (Thailand was not colonised by the British) and to modernise the country (Baker, 2012). The use of English was restricted to the court until 1996, when it became a compulsory subject at primary school level (Wongsothorn *et al.*, 2003). At present, learning English is compulsory from kindergarten school (age range 3-4 years) onwards. At university level, an English course is a requirement for all students regardless of their degrees.

English is normally taught by teachers who are native Thai speakers (Boonkit, 2002), and content is generally mediated through translation from English to Thai (Hayes, 2008). Other courses are normally taught in Thai. Outside the classroom, Thai is the main language used to communicate and used in the media. The status of English in Thailand is that of a foreign which is used to communicate with foreigners. Thailand is therefore classified as an 'expanding circle' country (Kachru, 2005). Thai L2 learners are mainly exposed to English in classes taught by speakers of Thai with Thai-accented English. They have little or no chances to practice their English in class or outside of class.

2.8 Research Aims

This study fills four main gaps as follows:

1. It provides a detailed investigation on the relationship between social and linguistic factors influencing fricative realisation by Thai learners of English. Hence the aim of this thesis is to find out factors that are related to L2 English fricative production that is deemed-target-like (Research Question 1). L2 English realisations were judged based on whether they are target-like or not and the factors which are correlated to target-like production will be presented, based on statistical analysis.

2. It explores the extent to which Thai learners of English produce target-like fricatives based on two types of analyses which were carried out: a) an impressionistic analysis and b) a sound

identification task. For the impressionistic analysis, it is an impressionistic account of L2 English fricative production by L2 Thai learners and then a comparison with L1 fricatives as produced by native speakers of English and Thai. Regarding the sound identification task, it explores the degree to which English fricatives produced by Thai learners leads to accurate sound identification by a group of native speakers of English. The thesis aims to investigate the extent to which the realisations of L2 English fricatives are native-like (Research Questions 2.1 and 2.2). In the impressionistic analysis, the realisations of L2 English, native Thai and native English were judged by an author. In the sound identification analysis, these sound realisations were judged by a group of native speakers of English. Statistical analysis were then applied to find out if the degree of L2 English production is more target-like as compared to that of native English and native Thai (for shared fricatives).

3. It explores the extent to which Thai learners of English produce native-like fricatives based on two types of analyses which were carried out: a) an accent-rating task and b) an acoustic analysis. For the accent-rating task, it investigates the degree of native-likeness in the realisations of L2 English fricatives produced by L2 Thai learners that were deemed target-like; these are then compared to those of L1 fricative counterparts as produced by native speakers of English and Thai. In the acoustic analysis, the study provides an in-depth description of realisations of L2 English fricatives that were deemed target-like and compare those with native Thai and native English fricatives. Therefore, this thesis aims to find out the extent to which the realisations of L2 English fricatives are native-like (Research Question 3). In the accent rating analysis, the realisations of L2 English, native Thai and native English were judged by a group of native speakers of English. Then in the acoustic analysis, these realisations were analysed with acoustic measurements. Statistical analysis was then applied to find out if the degree of L2 English

production is more native-like as compared to those of native English and native Thai (for shared fricatives).

4. It examines the production of L2 Thai learners who are advanced learners in the UK. The type of learning situation that is represented by the participants in this study is common and yet rarely examined from an L2 phonology point of view. As in Almbark (2012) and Shahidi (2010)'s studies, the learners in the present study had studied English in an EFL environment for many years. Equally, as typically found in the late AOA participants in Flege and colleagues' studies, the learners in the present study were based in the L2 country (the UK) at the time of testing. Crucially, however, these were not L2 learners who intended to settle in the UK, but rather transient visitors who still had ties with their home countries and their motivation to sound native-like for integrative purposes could not be taken for granted. Hence, this group of L2 learners might be closer to studies in which the subjects are in their home countries, rather than the L2 learners with extensive experience of using English in an L2 country considered by SLM or PAM-L2. Therefore, the aim of the present study is to test whether some of the predictions and hypotheses of CAH, PAM-L2, L2LP and SLM can be applied to English as a second language (ESL) learners in an L2 country with considerable experience of using the target language in a non-naturalistic setting, i.e. EFL learners whose main experience of English was in the classroom context, specifically L2 Thai university students living in the UK (Research Question 4). The results of this thesis will be discussed in light of these four models to find out to what extent they can account for these results.

Chapter 3. Impressionistic analysis of L2 fricatives and factors related to L2 fricative production

3.1 Introduction

This chapter presents a set of impressionistic analyses of L2 fricatives, including shared and non-shared fricatives, together with sociolinguistic analyses of L2 production. It comprises two main aims: i) to compare fricative production of Thai learners of English with that of native Thai and English speakers; and ii) to explore factors which relate to target-like production in L2 speech. The term ‘target-like’ production in this type of analysis refers to realisations that fall into the categorical IPA symbols that represent them based on the perception of the author, who is a trained phonetician and a native Thai speaker.

If L2 Thai learners have more difficulty producing non-shared sounds than shared sounds, the results will support the CAH. (see 2.2.4 for the hypotheses derived from these models). The difficulty here is determined by the percentage of L2 fricative realisations that are deemed target-like and whether their number is significantly lower than that of native English speakers. In terms of the sociolinguistic analysis, nine factors are tested for their correlation with L2 realisations that are deemed target-like: length of L2 exposure in the L2 country, LOR, gender, ideal L2 self, ought-to L2 self, L2 learning experience, anxiety, word frequency and vowel context.

3.2 Methodology

3.2.1 Speakers

Three groups of speakers participated in this experiment: speakers of L2 English (50 speakers), speakers of native English (20 speakers) and speakers of native Thai (20 speakers). All subjects were living in the UK at the time of this study. No participants reported having speech and/or hearing impairments.

Speakers of L2 English

To investigate L2 fricative production by L2 Thai learners, 50 Thai learners of English were recruited (27 females and 23 males). Their ages ranged from 18 to 51 years old (M = 29.48, SD = 6.16). The L2 Thai learners in this study had a homogeneous linguistic background; they spoke Thai as their mother tongue and had studied English as a foreign language (EFL) for approximately 17 years in compulsory courses at school and university (min = 15, max = 19). They were raised in Thailand and came to the UK as adults. They had a minimum length of residence in the UK of four months and a maximum length of residence of 57 months, and all of them were studying at the higher educational level in Newcastle-upon-Tyne, England at the time of the study. Their English backgrounds on arrival to the UK were assumed to be at the same level, i.e. reaching minimum level of English proficiency required to study in the UK. In order to explore the influence of exposure to English in the UK on their performance, LOR and amount of weekly English exposure were included as factors (amongst others) in the analysis. Table 7 shows a summary of information on the participants.

Table 7. Thai speakers of English

Female				**Male**			
Code	**Birthplace**	**LOR (month)**	**L2 Exposure (hour/week)**	**Code**	**Birthplace**	**LOR (month)**	**L2 Exposure (hour/week)**
100101	Surin	7	117	100201	Sakonnakhon	9	125
100102	Nakhonsrithammarat	7	50	100202	Nakhonsrithammarat	27	115
100103	Nakhonsrithammarat	24	100	100203	Nonthaburi	15	100
100104	Chachengsao	4	132	100204	Chiang Mai	5	69
100105	Bangkok	30	45	100205	Bangkok	8	76
100106	Nakhonsawan	4	75	100206	Bangkok	18	73
100107	Trang	21	145	100207	Khonkhen	5	66
100108	Chachengsao	5	79	100208	Rayong	4	56
100109	Prachuabkhririkhan	18	18	100209	Bangkok	7	34
100110	Bangkok	18	78	100210	Ratchaburi	4	66
100111	Srisaket	6	85	100211	Phitsanulok	32	72
100112	Chiang Mai	5	97	100213	Suratthani	16	94
100113	Suratthani	28	31	100214	Bangkok	5	65
100114	Suratthani	28	48	100215	Bangkok	40	126
100115	Bangkok	7	76	100216	Nakhonsawan	53	92
100116	Songkla	12	107	100217	Bangkok	24	82
100117	Ubonratchathani	16	122	100218	Bangkok	4	80
100118	Nakhonsawan	52	57	100219	Lampang	6	133
100119	Bangkok	17	134	100220	Bangkok	43	31
100120	Lampang	4	64	100221	Bangkok	52	21
100121	Phetchaburi	18	113	100223	Phitsanulok	54	75
100122	Bangkok	17	81	100224	Bangkok	14	47
100123	Mahasarakham	27	89	100225	Bangkok	7	60
100124	Bangkok	33	135				
100125	Sukhothai	27	59				
100126	Bangkok	4	32				
100127	Songkla	6	89				

Native speakers of English

20 British speakers (10 males and 10 females) were recruited regardless of regional background to reflect the actual university environment for Thai students, this being a melting pot of English accents (Major *et al.*, 2002). Their ages ranged from 20 to 51 years old (*M* = 30.65, *SD* = 8.95). All participants were Newcastle University students. Their production was used as a baseline to establish if there were any significant differences between L2 and native English production. Table 8 shows information on the English speakers who produced native English fricatives.

Table 8. English speakers

Female			**Male**		
Code	**Age**	**Birthplace**	**Code**	**Age**	**Birthplace**
200101	25	London	200201	31	Newcastle
200102	21	Dorset	200202	37	Newcastle
200103	31	Middlesbrough	200203	20	Sheffield
200104	51	Cambridge	200204	49	West Yorkshire
200105	29	Solihull	200205	30	London
200106	45	Bristol	200206	30	Norfolk
200107	28	London	200207	21	Northampton
200108	32	Reading	200208	31	Rugeley
200109	32	Bristol	200209	24	London
200110	26	Cumbria	200210	20	Reading

Native speakers of Thai

To find out whether target-like L2 fricative production is due to positive transfer for shared fricatives from the mother tongue, 20 of the Thai speakers from the L2 group above (10 males and 10 females) were selected to provide the native Thai control data. Only speakers with a length of residence (LOR) less than 10 months were recorded, in order to minimise the influence of L2 input in the L2 country. Their ages ranged from 20 to 39 years old (M = 26.45, SD = 4.22). Table 9 shows a summary of information on the Thai speakers who produced native Thai fricatives.

Table 9. Thai speakers producing native Thai fricatives

Female				Male			
Code	**Birthplace**	**LOR (month)**	**L2 Exposure (hour/week)**	**Code**	**Birthplace**	**LOR (month)**	**L2 Exposure (hour/week)**
100102	Nakhonsrithammarat	7	50	100201	Sakonnakhon	9	125
100104	Chachengsao	4	132	100204	Chiang Mai	5	69
100106	Nakhonsawan	4	75	100205	Bangkok	8	76
100108	Chachengsao	5	79	100207	Khonkhen	5	66
100111	Srisaket	6	85	100208	Rayong	4	56
100112	Chiang Mai	5	97	100209	Bangkok	7	34
100115	Bangkok	7	76	100210	Ratchaburi	4	66
100120	Lampang	4	64	100214	Bangkok	5	65
100126	Bangkok	4	32	100218	Bangkok	4	80
100127	Songkla	6	89	100219	Lampang	6	133

3.2.2 Stimuli

The stimuli consisted of English and Thai target words with initial fricatives that were either shared or not shared between the two languages. All stimuli were real words as it was thought this would mean speakers would produce them naturally, that this would represent their true pronunciation of the target sounds of interest. More details can be found below.

English stimuli

In terms of the English tested material, words with one of seven fricatives, /f, v, θ, ð, s, z, ʃ/, in initial position were used. /ʒ/ and /h/ were excluded as /ʒ/ does not occur in initial position in English and /h/ was considered the voiceless counterpart of a vowel, excluded from many previous studies (e.g., Ladefoged, 1982; Jongman *et al.*, 2000). As fricatives in some contexts were limited, fricatives in some positions and with some vowels could not be obtained. As a result of that, the targeted fricatives were grouped into 4 categories of following vowel contexts: front high /iː, ɪ/, front low /æ/, back high /ʊ, uː/ and back mid to low /ɔː, ɑː, ɒ/. The total number of tokens produced by L2 Thai and native English speakers was 14,070 (67 words × 3 times × 70 speakers). The word lists in English are given in Table 10. To minimize conscious awareness and thus monitoring of the fricatives being tested, another 61 words starting with other classes of consonants were added to the word lists as distractors.

Table 10. English wordlists

	Initial			
	Front high vowel	**Front low vowel**	**Back high vowel**	**Back mid to low vowel**
/f/	feel /fiːl/ (365.90)	fat /fæt/ (43.52)	foot /fʊt/ (85.02)	fought /fɔːt/ (9.03)
	fever /ˈfiːvə/ (3.94)	fan /fæn/ (10.18)	fool /fuːl/ (10.28)	fall /fɔːl/ (59.17)
	fit /fɪt/ (82.33)	fang /fæŋ/ (0.67)		farm /fɑːm/ ()
/v/	veal /viːl/ (0.48)	vat /væt/ (9.03)		vault /vɔːlt/ (0.29)
	visa /ˈviːzə/ (2.40)	van /væn/ (35.93)		volume /ˈvɒljuːm/ (18.35)
	veep /vip/ (0)	vampire /ˈvæmpaɪə/ (0.77)		vomit /ˈvɒmɪt/ (1.25)
	vision /ˈvɪʒən/ (10.47)			vase /vɑːz/ (3.75)
/θ/	thing /θɪŋ/ (1128.83)	thank /θæŋk/ (590.02)		thought /θɔːt/ (873.88)
	thick /θɪk/ (37.56)			Thorne /θoːn/ (1.25)
	thief /θiːf/ (2.98)			thorax /ˈθɔːræks/ (0)
/ð/	these /ðiːz/ (1258.42)	that /ðæt/ (21809.04)		
	this /ðɪs/ (5588.84)	than /ðæn/ (890.41)		
/s/	see /siː/ (2495.9)	sad /sæd/ (35.06)	soup /suːp/ (16.14)	sought /sɔːt/ (9.13)
	seat /siːt/ (35.45)	sat /sæt/ (76.85)	Sue /suː/ (40.92)	sock /sɒk/ (3.07)
		Sam /sæm/ (21.90)		saw /sɔː/ (210.76)
		sap /sæp/ (0.96)		sari /ˈsɑːrɪ/ (0.58)
/z/	zeal /ziːl/ (0.29)	zap /zæp/ (0.19)	zoom /zuːm/ (3.27)	zombie /ˈzɒmbɪ/ (1.63)
	zinc /zɪŋk/ (5.19)		zoo /zuː/ (3.36)	zara/ˈsɑːrɑː/ (0.38)
	zing /zɪŋ/ (0.58)			zoro /ˈzɒːrɒː/ (0)
	zee /zi/ (0.19)			
/ʃ/	sheet /ʃiːt/ (52.83)	shack /ʃæk/ (1.04)	shoot /ʃuːt/ (17.38)	shone /ʃɒn/ (1.06)
	shit /ʃɪt/ (67.34)	shat /ʃæt/ (0.48)		shot /ʃɒt/ (47.65)
	she /ʃiː/ (4118.5)	Shammy /ˈʃæmɪ/ (0.05)		shop /ʃɒp/ (193.85)
	ship /ʃɪp/ (48.78)			sharp /ʃɑːp/ (51.81)

NB: For each box in the table, the first one is the word; the second one in slashes is the IPA transcription; the last one in parentheses is word frequency taken from BNCweb (CQP-Edition) at Lancaster University.

Thai stimuli

The Thai stimuli comprised word lists with fricatives /f, s/ in initial position. Thai /h/ was also excluded from this study for a similar reason as in the English stimuli.

Each fricative was subcategorised into three groups according to the following vowels: front high vowel /iː/, front low vowel /aː/ and back high vowel /uː/. The total number of tokens produced was 1,080 (18 words × 3 times × 20 speakers). The word lists are shown in Table 11.

Table 11. Thai wordlists.

	Initial		
	Front high vowel	**Front low vowel**	**Back high vowel**
/f/	/fîːp/ 'become flat'	/fǎːn/ 'slice'	/fûːt/ 'swell'
	/fîːk/ 'conceal'	/fâːt/ 'thrash'	/fûːk/ 'mattress'
	/fîː/ 'sound of snoring'	/fâːk/ 'side'	/fuː/ 'rise'
/s/	/sǐːn/ 'precept'	/sàːt/ 'mat'	/sǔː/ 'you'
	/sîːk/ 'piece'	/sàːk/ 'coarse'	/sùːp/ 'suck'
	/sǐː/ 'color'	/sàːp/ 'musty smell'	/sùːt/ 'snuff'

3.2.3 Questionnaire

The questionnaire in this study was divided into two parts: i) personal information; ii) questions around motivation and anxiety. The first part explored three types of information: gender (male or female), English exposure (hours per week) and LOR (months). LOR was collected in months because the L2 Thai learners had come to the UK primarily to study; the maximum number of years that students can stay in the UK is five years and thus collecting LOR in months would provide more in-depth and useful information on the period of stay in the UK.

In terms of the section on motivation, this study employed the L2 Motivational Self System (Dörnyei, 2005) model which is composed of three factors: ideal L2 self, ought-to L2 self, L2 learning experience (see section 2.3.1); L2 anxiety was added as a factor apart from three factors in that system. Hence, there were four factors here: ideal L2 self, ought-to L2 self, L2 learning experience and L2 anxiety. Following Ghapanchi *et al.* (2011), each of these was measured using six questions or statements adapted from the questionnaire used in Papi's work (2010); ideal L2 self and ought-to L2 self were measured using statements, whereas L2 learning experience and L2 anxiety were measured using questions. The content in the statements and questions was adapted from the original version – focusing on English in general to English speaking. To avoid the L2 participants having difficulty in understanding the questionnaire, it was provided in both Thai and English. The consistency of the content in the two language versions was checked by three native speakers of Thai who were English lecturers at a university in Thailand. The respondents rated their motivation on a six-point Likert scale. For statements, the rating was ranked from 1 (strongly disagree) to 6 (strongly agree), and for questions, the rating was ranked from 1 (not at all) to 6 (very much). The questionnaire is provided in Appendix A.

3.2.4 Semi-structured interview

The participants were interviewed in Thai in order to obtain in-depth qualitative data providing information on attitudes towards L2 English usage. A semi-structured interview format was used to enable the L2 participants to provide clarification on their answers concerning complex issues (Barriball and While, 1994). It was hoped to enhance understanding of their attitudes towards L2 learning, which might be difficult to measure quantitatively. The questions in the semi-structured interview were as follows:

1. As an L2 learner, how do you perceive the British accent?
2. Would you prefer to speak English like a native English speaker, or would you not mind retaining some Thai accent?
3. How do you feel about having a Thai accent when speaking English?
4. Which of these four skills, reading, writing, listening and speaking, do you use most in the UK?
5. What future plans do you have when you have completed your studies here in the UK?
6. Have you experienced communication difficulties due to your Thai accent when speaking English?

3.2.5 Data collection

Each speaker was recorded separately as they produced the words that they saw on the computer screen. PowerPoint was used to run this task. The order of words was randomised, and once speakers had produced the first randomised block, they would produce the second block and the third block, respectively. Words were produced in carrier phrases. In the English stimuli, speakers produced the words in the context of ‘Say___again’, whereas in the Thai stimuli, speakers produced the words in the phrase ‘/oo.kʰee____ìik.kʰráŋ/ ‘Okay____again’ three times. Although /oo.kʰee/ ‘okay’ is an English loanword in Thai, it was selected for use in the Thai carrier phrase due to its appropriateness to the speaking context and the similarity of the final vowel of the second syllable to ‘say’ in the English carrier phrase, which facilitated comparison between Thai and English fricatives. All recordings were carried out in a soundproof booth in a phonetics laboratory at Newcastle University.

The participants’ voices were recorded via a high-quality microphone (Behringer ECM8000) with a frequency response from 15 Hz to 20 kHz. The microphone was placed approximately 5 cm from the participant’s mouth at a 45-degree angle to prevent speakers impinging on the microphone (Jongman *et al.*, 2000). This microphone was connected to the recorder (Edirol R-44) in which the recordings were sampled at 44 kHz, bin mono channel (16-bit quantisation).

After that, they completed the questionnaire for personal information followed by the motivation assessment. When they had finished the questionnaire, the author entered the room to converse with them using the conversation guide in the semi-structured interview which was carried out in their native language (Thai) to minimise the L2 barrier. The questionnaire and interview took approximately 45 minutes, including breaks between each activity.

3.2.6 Data analysis

Impressionistic data analysis

For the impressionistic analysis, the speakers’ productions were transcribed using a broad IPA transcription with the purpose of signalling whether the production was deemed target-like (rather than native-like). The author, while phonetically trained, shared the same linguistic background with the L2 Thai learners and spoke English with a Thai accent. Praat was therefore used to annotate the target words for repeated listening and IPA symbols were used in the transcription with a focus on the initial fricatives. The realisation that was deemed target-like was judged based on three qualities, i.e. voicing, place and manner of articulation. In cases where the sound was not perceived to meet these three qualities, it was judged as a realisation that was deemed non-target-like.

In terms of statistical analyses, studies analysing L2 sounds have traditionally use a combination of descriptive statistics such as percentages and frequencies (e.g. Brière and Chiachanpong, 1980; Zuengler, 1988; Burkardt, 2008) and inferential statistics such as t-test (e.g. Wester *et al.*, 2007) and/or Analysis of Variance (e.g. Gass and Varonis, 1984; Alosh, 1987). Descriptive statistics are useful in describing the observed patterns in the data, while inferential statistics are useful in making predictions about a given population, and generalisations can be usually drawn from their results (Goodwin, 2010). Most research on L2 phonology also uses a combination of randomly selected speakers and item tests, and using repeated measures ANOVA typically requires the researcher to average the multiple data points per speaker and per item. The drawback of using traditional tests such as t-test and ANOVA is that they do not allow the researcher to take into account individual variation (although repeated measures ANOVA does, albeit averaging across multiple repetitions and items). The use of Linear Mixed effects Model (LMM) through the Generalised Linear Models has started to be well established in the L2 Phonology literature and beyond. LMMs are also more efficient in dealing with unbalanced data, data with missing observations and controlling for individual subjects and items; these do not require any type of correction in case of violations as is the case with repeated measures ANOVA (Lindstrom and Bates, 1990; Cunnings, 2012). As LMMs are known to be assumption-free, they are more robust against violations of sphericity and homoscedasticity (Quene and Bergh, 2004).

For this chapter, as the focus of the impressionistic analysis was to compare L2 fricative production with that of native English and Thai speakers, a set of binomial generalised linear mixed models (GLMMs) were estimated using the *lme4* package in R statistical software (Bates *et al.*, 2014), together with the use of percentages. If the number of productions by L2 learners that were deemed target-like was significantly lower than that of native speakers of L2 and/or the percentage of L2 production that was deemed target-like was low, this was taken to suggest that the target fricative is difficult for L2 Thai learners to produce.

Whether the sound was deemed to have been realised as target-like or not was the dependent variable (target-like/non-target-like); hence the dependent variable was binomial. The independent variable was language group. There were three language groups for shared fricatives (native English/native Thai/L2 English) and two language groups for non-shared fricatives (native English/L2 English). The model comparison was done between the model with the speaker and item as random intercepts and the model with the item as random intercept and the speaker and vowel as random intercept and slope.[11, 12] No interactions of factors were explored during model selection. The examples of the formulae used for model comparison are as follows:

```
> glmer50 <- glmer(realisation ~ (1|item) + (1|speaker) +
             language, data=data1.frame, family=binomial)

> glmer51 <- glmer(realisation ~ (1|item) + (vowel|speaker) +
             language, data=data1.frame, family=binomial)
```

The *anova* function was then used to show the Akaike information criterion (AIC), which was used for overall model comparisons according to the ‘smaller is better’ principle (Zheng *et al.*, 2013). If there was a significant difference between these two models, the model with the smaller AIC value was chosen; however, if there was no significant difference between the two models, the model with speaker and item as random intercepts was selected as this model was simpler. The results reported in this study are from the optimal model after model comparisons.

As the *glmer* function yielded dummy output, there was a problem comparing the three language groups for shared fricatives. To see all pairs of language contrasts for shared sounds, Tukey's HSD post-hoc tests were performed on the language groups using the *lsmeans* package in R statistical software (Lenth, 2014). The multiple pairwise comparisons were done only on the optimal model. The p values in GLMMs and post-hoc tests reported are one-tailed. An example of R code for Tukey's HSD post-hoc test is as follows:

```
lsmeans(glmer51, pairwise ~ language, adjust="tukey")
```

[11] In some studies, the model comparisons might start from an empty model; however, comparing an empty model with these models was not the focus of the analysis of the number of productions that were deemed target-like of L2 compared to those of L1 productions.

[12] The vowel context is within-subjects variable which might affect participants.

Data analysis of sociolinguistic factors.

In order to explore the relationship between L2 production that was deemed target-like and external factors, together with the direction of influence of these factors, binomial generalised linear mixed models (GLMMs) were estimated using the *lme4* package in R statistical software (Bates *et al.*, 2014). The independent variables were vowel contexts, gender, LOR, English exposure, word frequency, ideal L2 self, ought-to L2 self, L2 English experience and L2 anxiety. The dependent variable was either target-like or non-target-like speech realisation.

For the motivational factors, each set of motivation was checked for its internal reliability using Cronbach's alpha in SPSS to ensure that all sets had a high level of reliability. The results showed that all aspects of motivation received scores of internal consistency higher than 0.75, reaching the suggested threshold for L2 research of 0.7 (Dörnyei, 2002); hence, none of the questions or statements about motivation were deleted.

Six questions or statements for each factor were combined and averaged to have the overall level for target factors.[13] Many studies, such as Leavy *et al.* (2015) and Medallon (2013) had the range width of the first level as 1.49 and the ranges of levels before the last one as 0.99. As four aspects were assessed here: ideal L2 self, ought-to L2 self, L2 English learning experience and English anxiety, the first three aspects were interpreted as the higher the value, the more positive the interpretation was while the last one, English anxiety, was interpreted as the higher the value the more negative the interpretation was. They were also set into new values according to their averaged score:

- 0 - 1.49 = level 1
- 1.50 - 2.49 = level 2
- 2.50 - 3.49 = level 3

[13] From the questionnaire in Appendix A, items for ideal L2 self were: 1, 4, 8, 12, 16, 20; items for ought-to L2 self were: 2, 5, 9, 13, 17, 21; items for L2 English learning experience were: 23, 26, 29, 33, 31, 35; items for English anxiety were: 24, 27, 30, 32, 34, 36.

- 3.50 - 4.49 = level 4
- 4.50 - 5.49 = level 5
- 5.50 - 6.00 = level 6.

Word frequency was taken from the frequency of spoken words in the BNCweb (CQP-Edition) at Lancaster University. It is based on 100 million words from written and spoken English from various sources of the British National Corpus (BNC). The frequency was the frequency of spoken instances per million words. For example, the word ‘zing’ in spoken texts appears six times in 10,409,858 words, which is 0.58 instances per million words.

There were no missing data for these GLMMs as all realisations of the dependent variable were coded as either target-like or non-target-like, while all the factors comprising the independent variables had data from L2 learners or items. In each model comparison, the model with speaker and item as random intercepts was compared to the model with the item as random intercept and speaker and vowel as random intercept and slope. Examples of the R code are as follows:

```
glmer2 <- glmer (realisation ~ (1|item) + (1|speaker) + vowel +
          sex + lor + exposure + frequency + ideal + ought +
          experience + anxiety, data=data.frame, family=binomial)

glmer3 <- glmer (realisation ~ (1|item) + (vowel|speaker) + vowel
          + sex + lor + exposure + frequency + ideal + ought +
          experience + anxiety, data=data.frame, family=binomial)
```

Similarly to GLMMs for the impressionistic studies, the results presented are from the best model after model comparisons. As the *glmer* function yielded dummy output, as in the GLMM analysis of the impressionistic analysis, Tukey's HSD post-hoc tests were performed on vowel context to see all pairs using the *lsmeans* package in R statistical software (Lenth, 2014). Similar to the GLMMs for impressionistic task, all p values are one-tailed. Only factors that showed a significant effect for the target fricatives are reported. Table 12 shows the coding of each independent variable for the GLMMs.

Table 12. GLMM coding for the sociolinguistic investigation

Factor	Variable	Type of variable
External factor (questionnaire)	1. Length of English exposure in the UK (hour/week)	Interval
	2. Length of residence (LOR) (month)	Interval
	3. Gender	Factor (male/female)
	4. Ideal self	Interval (6-point scale)
	5. Ought-to self	Interval (6-point scale)
	6. English learning experience	Interval (6-point scale)
	7. English anxiety	Interval (6-point scale)
Internal factor (word lists)	8. Word frequency	Interval
	9. Vowel context	Factor (front high, front low, back high, back mid to low)

3.3 Results

3.3.1 Impressionistic analysis of shared fricatives

L2 English /f/

Table 13 shows the overall results of the auditory analysis with the frequency and percentage of L2 English /f/ produced by Thai learners compared to those by native speakers of English and Thai. It shows that the three groups of speakers had high occurrences of production that was deemed target-like. For the statistical analysis, Tukey's HSD post-hoc test based on GLMM (Table 14) showed that there were no significant differences in the number of productions that were deemed target-like in all three language groups (p = 0.50 for all language pairs), suggesting that the L2 Thai learners had no difficulty producing L2 English /f/ in initial position. In addition, L2 English /f/ was also occasionally realised as [w, v, t, b, s], for example /fɑːm/ as [wɑːm]. The realisations of native English /f/ were similar to those by L2 Thai learners but were occasionally realised as [v, p] with small frequencies. All realisations of native Thai /f/ were deemed target-like. The GLMM for the relationship between the factors considered and production that was deemed target-like of /f/ showed no significant factors in relation to L2 realisations that were deemed target-like (see Table 15). Tukey's HSD post-hoc test for vowel contexts showed no significant effects of all pairs (p = 0.50 for back high vowel context as compare to the other three vowel contexts; p = 0.27 for back mid to low vowel context as compared to front high vowel context; p = 0.35 for back mid to low context as compared to front low vowel context; p = 0.49 for front high vowel context as compared to front low vowel context).

Table 13. Impressionistic results of /f/ production by L2 Thai learners, British speakers and Thai speakers

Realisation	L2 Thai learners		British speakers		Thai speakers	
	Frequency	%	Frequency	%	Frequency	%
[f]	1640	99.39	657	99.5	540	100
[w]	6	0.36	-	-	-	-
[v]	1	0.06	1	0.2	-	-
[t]	1	0.06	-	-	-	-
[b]	1	0.06	-	-	-	-
[s]	1	0.06	-	-	-	-
[p]	-	-	2	0.3	-	-
Total	1650	100	660	100	540	100

Table 14. Estimates for intercept and two language groups from GLMM model for impressionistic study of /f/

	Estimate	Std. Error	z-value	Pr(>|z|)
(Intercept)	9.8773	3.4931	2.828	0.002345
L2 English	-0.3245	3.9693	-0.082	0.467425
Native Thai	15.9722	1538.0862	0.01	0.495855

Table 15. Estimates for intercept and factors from GLMM model for impressionistic study of /f/

	Estimate	Std. Error	z-value	Pr(>|z|)
(Intercept)	-25.700	9490.000	-0.003	0.499
Vowel (back mid to low)	17.600	9490.000	0.002	0.4995
Vowel (front high)	19.400	9490.000	0.002	0.499
Vowel (front low)	19.000	9490.000	0.002	0.499
Male	0.757	1.400	0.542	0.294
LOR	0.011	0.044	0.257	0.3985
L2 exposure	-0.003	0.020	-0.161	0.436
Frequency	-0.001	0.004	-0.311	0.378
Ideal L2 self	-0.332	1.020	-0.324	0.373
Ought-to L2 self	0.431	0.909	0.474	0.3175
L2 experience	0.299	0.959	0.312	0.3775
L2 anxiety	-0.480	0.941	-0.509	0.305

L2 English /s/

Table 16 shows that whereas Thai and British speakers had 100% realisations that were deemed target-like for their L1 productions, L2 Thai learners had various patterns of realisations. Most target productions were deemed to have been realised as target-like [s], but some were deemed to have been realised as [ʃ, z, θ, t, ɹ, tʰ, t͡ʃ, t͡ɕ, ʒ], e.g. /suː/ as [ʃuː] and /suː/ as [zuː]. Tukey's HSD post-hoc test based on GLMM (Table 17) showed that there were no significant differences in the number of productions that were deemed target-like in all three language groups (p = 0.50 for all language pairs), suggesting that the L2 Thai learners had no difficulty producing L2 English /s/ in initial position. Specific to the L2 Thai learners, in terms of sociolinguistic factors influencing of L2 English /s/ production, the GLMM showed that the amount of L2 English exposure was correlated negatively with L2 production that was deemed target-like (b = -0.02, SE = 0.01, p < 0.01, see Table 18). Tukey's HSD post-hoc test for vowel contexts showed that the back high vowel context as compared to front low vowel context in Table 18 was correlated negatively with L2 production that was deemed target-like like (b = -2.56, SE = 1.21, p < 0.05) and no significant effects of other vowel pairs (p = 0.44 for back high vowel context as opposed to back mid to low vowel context; p = 0.33 for back high vowel context as opposed to front high vowel context; p = 44 for back mid to low vowel context as compared to front high vowel context; p = 0.17 for back mid to low vowel context as compared to front low vowel context; p = 0.49 for front high vowel context as compared to front low vowel context). Figure 2 illustrates the relationship between /s/ realisation and L2 English exposure whereas Figure 3 shows the relationship between /s/ realisation and vowel context.

Table 16. Impressionistic results of /s/ production by L2 Thai learners, British speakers and Thai speakers

Realisation	L2 Thai learners		British speakers		Thai speakers	
	Frequency	%	Frequency	%	Frequency	%
[s]	1900	97.4	780	100	540	100
[z]	13	0.7	-	-	-	-
[ʃ]	20	1.0	-	-	-	-
[θ]	9	0.5	-	-	-	-
[t]	2	0.1	-	-	-	-
[ɹ]	1	0.1	-	-	-	-
[tʰ]	2	0.1	-	-	-	-
[t͡ʃ]	1	0.1	-	-	-	-
[t͡ɕ]	1	0.1	-	-	-	-
[ʒ]	1	0.1	-	-	-	-
Total	1950	100	780	100	540	100

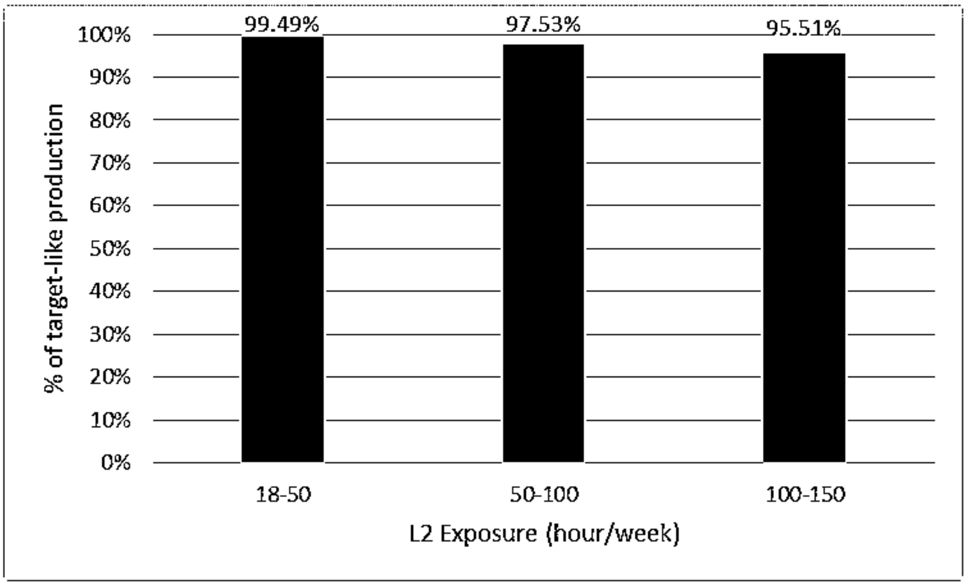

Figure 2. Relationship between L2 English /s/ productions deemed target-like and the amount of L2 English exposure (hour/week)

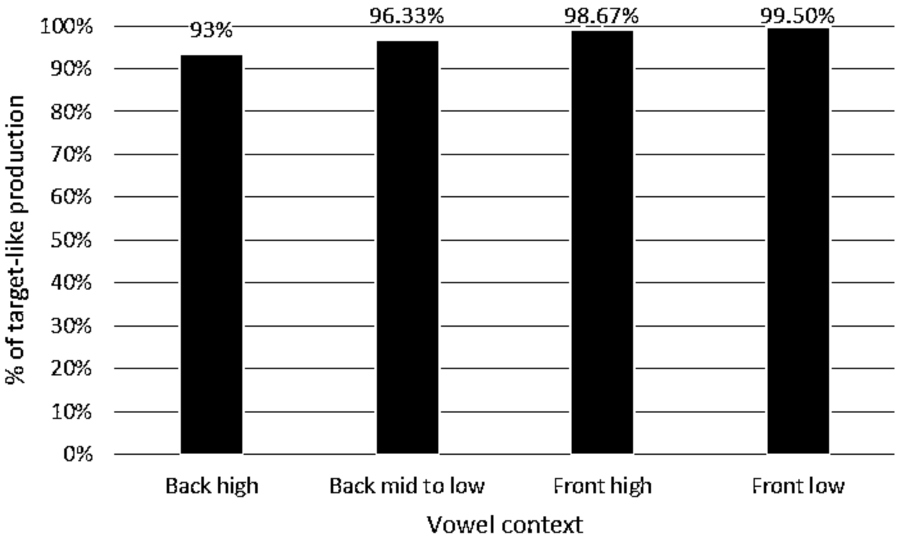

Figure 3. Relationship between L2 English /s/ productions deemed target-like and vowel context

Table 17. Estimates for intercept and two language groups from GLMM model for impressionistic study of /s/

	Estimate	**Std. Error**	**z-value**	**Pr(>|z|)**
(Intercept)	72.16	2516478	0	0.5
L2 English	-66.5	2516478	0	0.5
Native Thai	39.69	3832510	0	0.5

Table 18. Estimates for intercept and factors from GLMM model for impressionistic study of /s/

	Estimate	**Std. Error**	**z-value**	**Pr(>|z|)**
(Intercept)	6.4004607	1.9874413	3.22	0.00064
Vowel (back mid to low)	0.7807247	1.0656951	0.733	0.2319
Vowel (front high)	2.0109199	1.7457712	1.152	0.124685
Vowel (front low)	**2.5640686**	**1.2144232**	**2.111**	**0.03737**
Male	0.6425686	0.4378822	1.467	0.071125
LOR	-0.0154041	0.0143899	-1.07	0.142205
L2 exposure	**-0.0168702**	**0.0071171**	**-2.37**	**0.008885**
Frequency	-0.0003942	0.0007979	-0.494	0.31063
Ideal L2 self	0.1880306	0.2825762	0.665	0.25289
Ought-to L2 self	-0.0117886	0.2243171	-0.053	0.479045
L2 experience	-0.283919	0.2471706	-1.149	0.125345
L2 anxiety	-0.265216	0.277842	-0.955	0.1699

3.3.2 Impressionistic analysis of non-shared fricatives

L2 English /v/

Table 19 demonstrates that about 10% of L2 English /v/ productions were deemed to have been realised as target-like, whereas most realisations of native English /v/ were deemed to have been realised as target-like. The GLMM (Table 20) showed that the number of L2 productions of /v/ that were deemed target-like was significantly lower than that produced by native speakers of the L2 (b = -7.55, SE = 0.74, p < 0.01), confirming that L2 English /v/ was difficult for L2 Thai learners. Apart from target-like realisations of /v/ was also transcribed as [f, b, w, t, d, ð, p], with [w] showing the highest frequency of /v/ substitution, such as [ˈwɪ.t͡ɕʰan] for /ˈvɪ.ʒən/ and [fæn] for /væn/. Native English /v/ was occasionally realised as [f, b, w, d, p]. Figure 4 demonstrates that the percentage of /v/ productions that were deemed target-like was low for L2 Thai learners, but high for native speakers of L2.

Table 19. Impressionistic results of /v/ production by L2 Thai learners and British speakers

Realisation	**L2 Thai learners**		**British speakers**	
	Frequency	**%**	**Frequency**	**%**
[v]	217	13.2	597	90.5
[f]	197	11.9	58	8.8
[b]	22	1.3	2	0.3
[w]	1205	73.0	1	0.2
[t]	2	0.1	-	-
[d]	5	0.3	1	0.2
[ð]	1	0.1	-	-
[p]	1	0.1	1	0.2
Total	1650	100	660	100

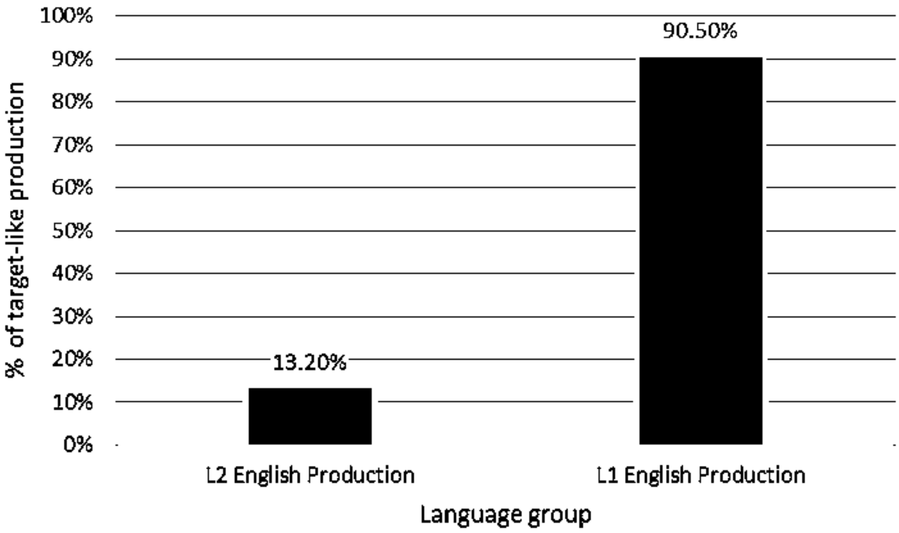

Figure 4. L2 productions deemed target-like of /v/ in the two groups of speakers

The GLMM (Table 21) testing sociolinguistic factors showed that the number of L2 /v/ productions that were deemed target-like was significantly lower in male speakers as compared to female speakers (b = -1.93, SE = 0.86, $p < 0.05$) and when L2 anxiety increased (b = -1.08, SE = 0.62, $p < 0.05$); on the other hand, the number higher when the ideal L2 self increased (b = 1.36, SE = 0.55, $p < 0.01$) (Figure 5, Figure 6 and Figure 7). Tukey's HSD post-hoc test for vowel contexts showed no significant effects of any pairs (p = 0.47 for back mid to low vowel context as compared to front high vowel context; p = 0.41 for back mid to low vowel context as compared to front low vowel context; p = 0.49 for front high vowel context as compared to front low vowel context).

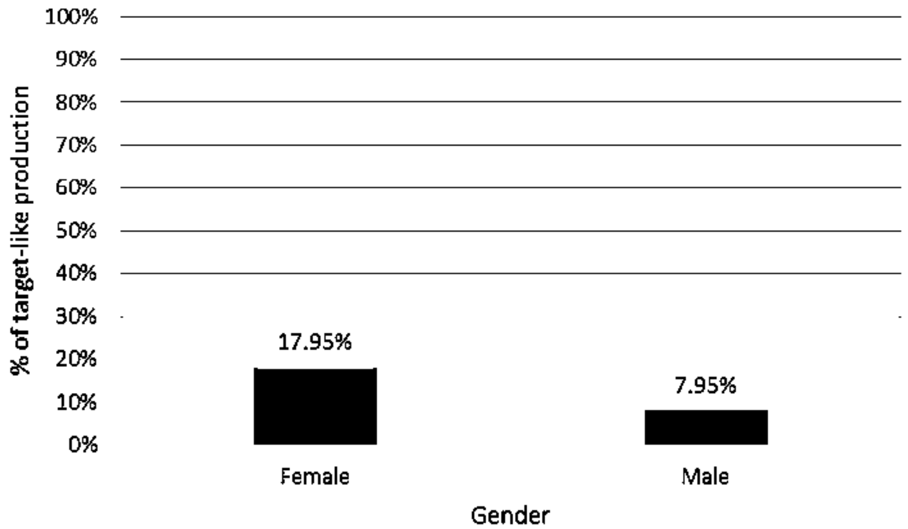

Figure 5. Relationship between L2 English /v/ productions deemed target-like and gender of L2 speakers

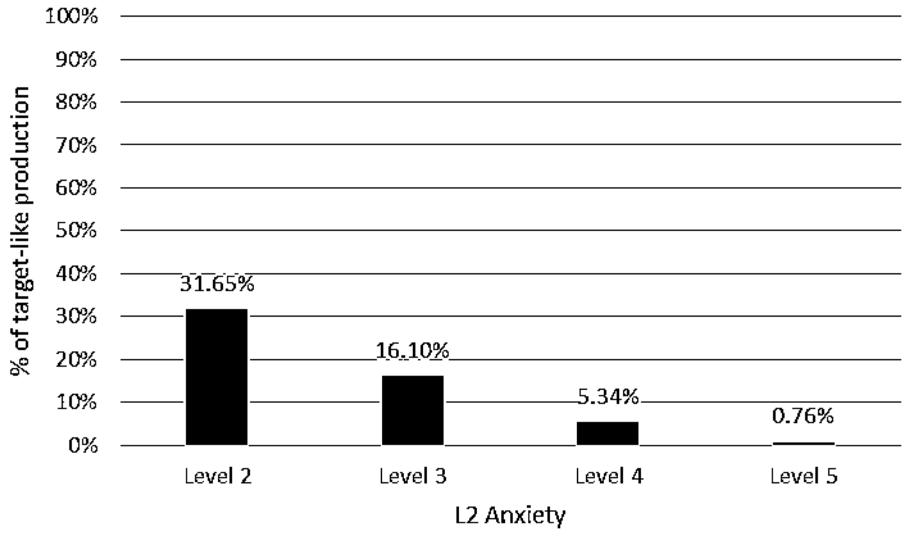

Figure 6. Relationship between L2 English /v/ productions deemed target-like and L2 anxiety

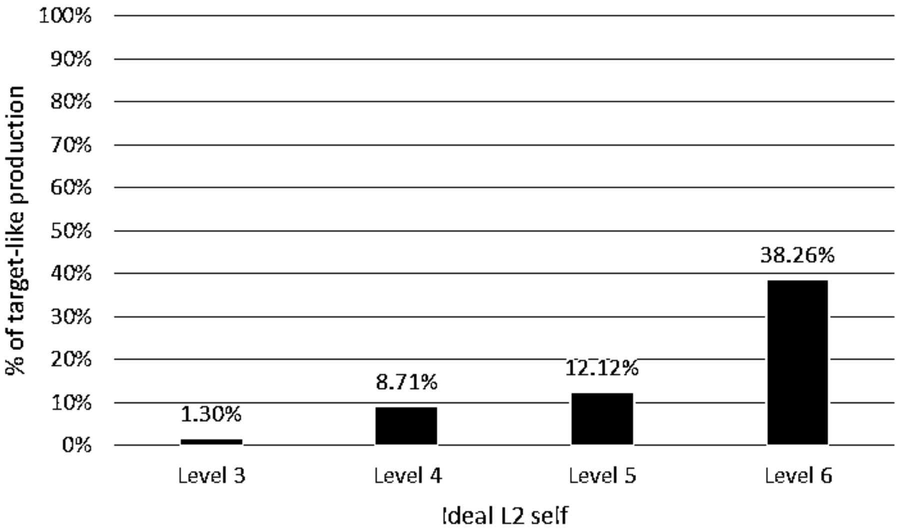

Figure 7. Relationship between L2 English /v/ productions deemed target-like and ideal L2 self

Table 20. Estimates for intercept and one language group from GLMM model for impressionistic study of /v/

	Estimate	Std. Error	z-value	Pr(>|z|)
(Intercept)	3.6305	0.6235	5.823	0.000
L2 English	-7.5534	0.7441	-10.151	0.000

Table 21. Estimates for intercept and factors from GLMM model for impressionistic study of /v/

	Estimate	Std. Error	z-value	Pr(>|z|)
(Intercept)	-4.714087	3.9441553	-1.195	0.116
Vowel (front high)	0.1888064	0.5826731	0.324	0.37295
Vowel (front low)	0.2670646	0.4517214	0.591	0.2772
Male	**-1.9289811**	**0.8613481**	**-2.24**	**0.01255**
LOR	0.0323251	0.0311762	1.037	0.1499
L2 exposure	0.0007483	0.0135844	0.055	0.47805
Frequency	0.0153141	0.0141169	1.085	0.139
Ideal L2 self	**1.3607357**	**0.5508752**	**2.47**	**0.00675**
Ought-to L2 self	-0.3720881	0.4929483	-0.755	0.2252
L2 experience	-0.0784952	0.4616685	-0.17	0.4325
L2 anxiety	**-1.0804027**	**0.6165807**	**-1.752**	**0.03985**

L2 English /θ/

Table 22 shows that the L2 learners produced only a small percentage of /θ/ production that was deemed target-like (30.48%). The GLMM (Table 23) showed that the number of L2 productions of /θ/ that were deemed target-like was significantly lower than that produced by native speakers (b = -10.52, SE = 1.99, p < 0.01), confirming that L2 English /θ/ was difficult for L2 Thai learners. [t] was the highest substitution for L2 English /θ/, e.g. /θiːf/ realised as [tiːf], followed by [d, t^h, deletion, s, t͡ɕ, t͡ʃ, ɕ, ʃ, p], e.g. /θɔːt/ realised as [sɔːt]. In the productions of native speakers, the percentage of /θ/ realisations which were deemed to have been realised as the canonical [θ] was 97.62%, while other realisations included [t].

Figure **8** illustrates that /θ/ production that was deemed target-like was low for L2 Thai learners, but high for native speakers of L2.

Table 22. Impressionistic results of /θ/ production by L2 Thai learners and British speakers

Realisation	L2 Thai learners		British speakers	
	Frequency	**%**	**Frequency**	**%**
[θ]	320	30.48	410	97.62
[t]	504	48.00	10	2.38
[d]	4	0.38	-	-
[tʰ]	181	17.24	-	-
[deletion]	1	0.10	-	-
[s̪]	18	1.70	-	-
[t͡ɕ]	8	0.76	-	-
[t͡ʃ]	10	0.95	-	-
[ɕ]	2	0.19	-	-
[ʃ]	1	0.10	-	-
[p]	1	0.10	-	-
Total	1050	100	420	100

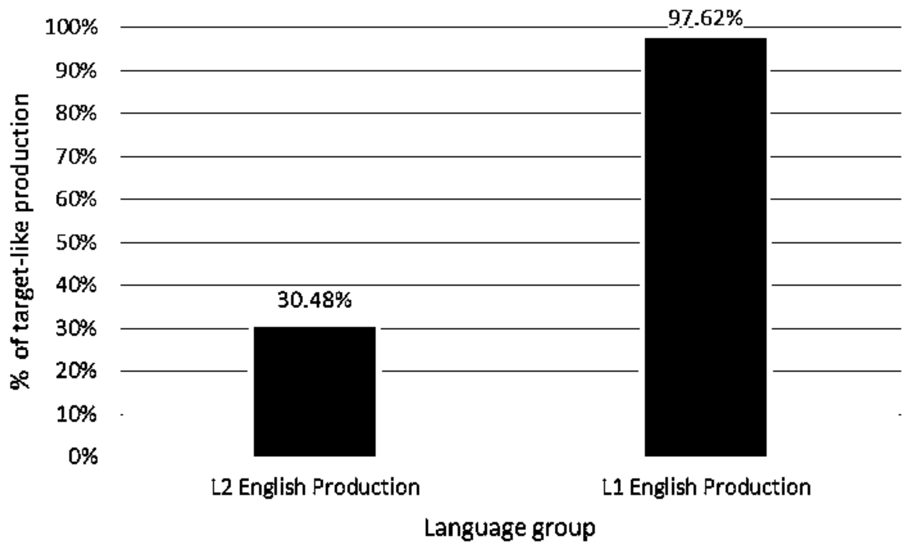

Figure 8. L2 productions deemed target-like of /θ/ in the two groups of speakers

The GLMM (Table 24) for social factors showed that L2 /θ/ production that was deemed target-like significantly was higher when the degree of ideal L2 self increased (b = 2.02, SE = 0.58, p < 0.01), as shown in Figure 9, but lower when the degree of L2 anxiety increased (b = -1.23, SE = 0.60, p < 0.05), as shown in Figure 10. L2 /θ/ target-like production had potential to be lower in the front high vowel compared to back mid to low vowel contexts (p = 0.07). Tukey's HSD post-hoc test for vowel contexts showed no significant effects of all pairs (p = 0.14 for back mid to low vowel context as compared to front high vowel context; p = 0.50

for back mid to low vowel context as compared to front low vowel context; p = 0.31 for front high vowel context as compared to front low vowel context).

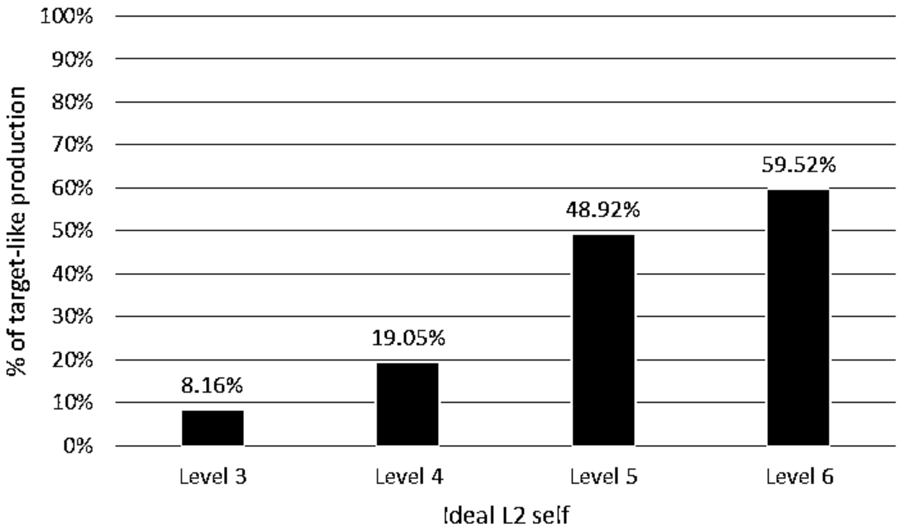

Figure 9. Relationship between L2 English /θ/ productions deemed target-like and ideal L2 self

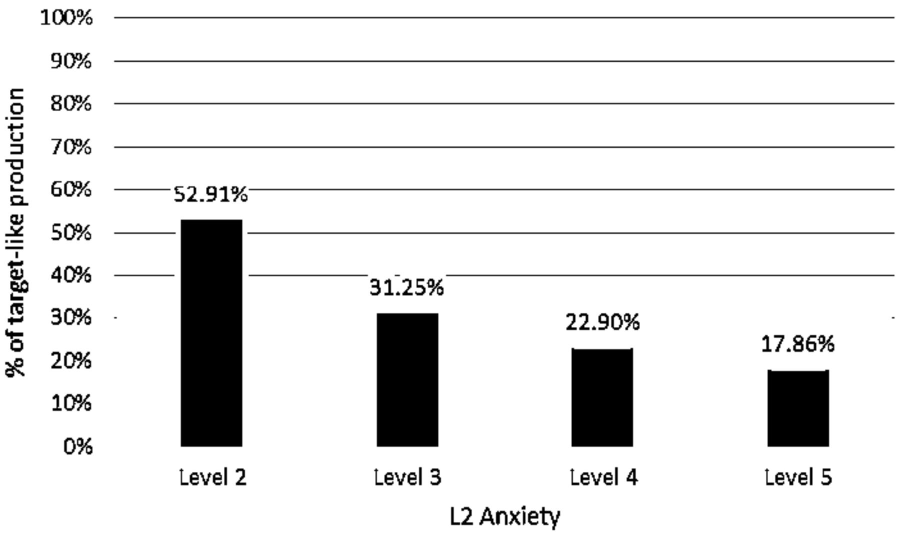

Figure 10. Relationship between L2 English /θ/ productions deemed target-like and L2 anxiety

Table 23. Estimates for intercept and one language group from GLMM model for impressionistic study of /θ/

	Estimate	**Std. Error**	**z-value**	**Pr(>|z|)**
(Intercept)	8.176	1.91	4.281	0.000
L2 English	-10.515	1.989	-5.286	0.000

Table 24. Estimates for intercept and factors from GLMM model for impressionistic study of /θ/

	Estimate	**Std. Error**	**z-value**	**Pr(>|z|)**
(Intercept)	-8.21486	4.207308	-1.953	0.025438
Vowel (front high)	-0.67537	0.446882	-1.511	0.0653575
Vowel (front low)	-0.06206	0.714908	-0.087	0.465413
Male	0.290018	0.961971	0.301	0.3815235
LOR	-0.02269	0.033608	-0.675	0.249828
L2 exposure	0.003912	0.01464	0.267	0.394651
Frequency	0.000106	0.000395	0.269	0.3940505
Ideal L2 self	**2.024157**	**0.579886**	**3.491**	**0.000241**
Ought-to L2 self	-0.01206	0.541494	-0.022	0.4911125
L2 experience	0.300143	0.52558	0.571	0.283976
L2 anxiety	**-1.23011**	**0.599188**	**-2.053**	**0.020038**

L2 English /ð/

Table 25 shows that the proportion of /ð/ productions that were deemed target-like was low among L2 Thai learners (7.83%), as the majority of realisations were [d]-like, whereas this sound was mostly deemed to have been realised as target-like in the production of British speakers. The GLMM (Table 26) showed that the number of L2 /ð/ productions that were deemed target-like was significantly lower than that produced by native speakers (b = -6.20, SE = 0.72, p < 0.01), confirming that English /ð/ was difficult for L2 Thai learners. L2 English /ð/ was also deemed to have been realised as [t, θ, t͡ɕ, s], e.g. /ðɪs/ realised as [dɪs]. Figure 11 shows that the percentage of /ð/ productions that were deemed target-like was low for L2 Thai learners, but high for native speakers of the L2. From a sociolinguistic perspective, the GLMM (Table 27) showed that the proportion of target-like L2 /ð/ production was significantly was higher when the degree of LOR increased (b = 0.07, SE = 0.04, p < 0.05). Moreover, a front low vowel context as compared to front high vowel showed a negative but non-significant correlation with target-like L2 production (p = 0.06), while ideal L2 self (p = 0.07) and word frequency (p = 0.06) showed a positive but non-significant correlation with target-like L2 production. Tukey's HSD post-hoc test for vowel contexts showed a positive tendency of target-like L2 /ð/ productions in front high context compared to front low context (p = 0.06).

Table 25. Impressionistic results of /ð/ production by L2 Thai learners and British speakers

Realisation	**L2 Thai learners**		**British speakers**	
	Frequency	**%**	**Frequency**	**%**
[ð]	47	7.83	186	77.50
[d]	487	81.17	34	14.17
[t]	48	8.00	1	0.42
[θ]	16	2.67	19	7.92
[t͡ɕ]	1	0.17	-	-
[s]	1	0.17	-	-
Total	600	100	240	100

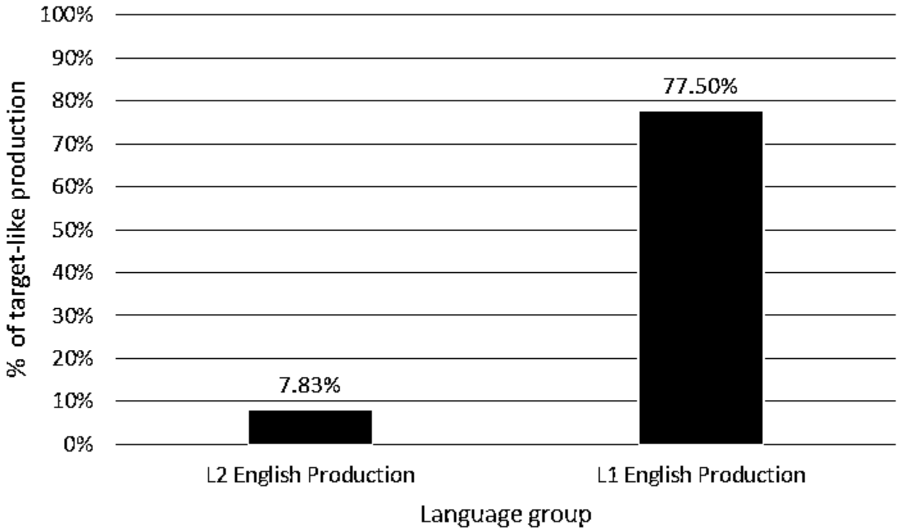

Figure 11. L2 English /ð/ productions deemed target-like in the two groups of speakers

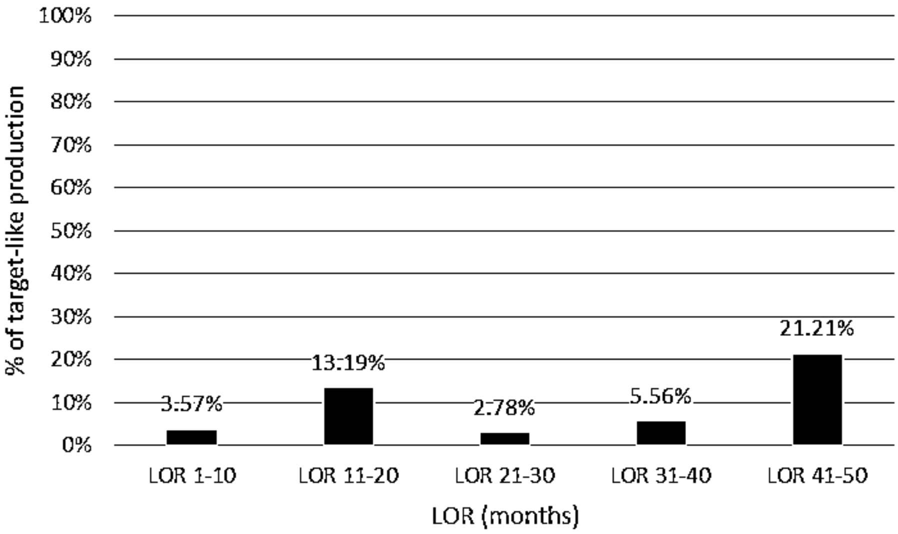

Figure 12. Relationship between L2 English /ð/ productions deemed target-like and LOR

Table 26. Estimates for intercept and one language group from GLMM model for impressionistic study of /ð/

	Estimate	**Std. Error**	**z-value**	**Pr(>|z|)**
(Intercept)	1.8119	0.547	3.312	0.000463
L2 English	-6.2002	0.7196	-8.616	0.000000

Table 27. Estimates for intercept and factors from GLMM model for impressionistic study of /ð/

	Estimate	**Std. Error**	**z-value**	**Pr(>|z|)**
(Intercept)	**-11.200**	**5.560**	**-2.005**	**0.0225**
Vowel (front low)	-0.694	0.451	-1.538	0.06195
Male	0.753	1.310	0.575	0.2826
LOR	**0.065**	**0.037**	**1.752**	**0.0399**
L2 exposure	-0.009	0.020	-0.45	0.3263
Frequency	0.000	0.000	1.517	0.06465
Ideal L2 self	1.150	0.769	1.488	0.0684
Ought-to L2 self	0.536	0.774	0.692	0.2444
L2 experience	-0.124	0.654	-0.189	0.4249
L2 anxiety	-0.383	0.788	-0.486	0.3136

L2 English /z/

Table 28 shows that L2 English /z/ was mostly deemed to have been realised as [s] (78.2%), followed by [z] (21.6%). The GLMM (Table 29) showed that the number of L2 /z/ productions that were deemed target-like was significantly lower than that produced by native speakers of the L2 (b = -7.20, SE = 0.89, p < 0.01), confirming that L2 English /z/ was difficult for L2 Thai learners. All substitutions for L2 English /z/ were voiceless for both L2 Thai learners and British speakers, such as /zuː/ deemed to have been realised as [suː]. For British speakers, this sound was deemed to have been realised mainly as target-like (92.8%), followed by [s] (7.2%). Figure 13 illustrates that the percentage of /z/ productions that were deemed target-like was low for L2 Thai learners, but high for native speakers of L2.

Table 28. Impressionistic results of /z/ production by L2 Thai learners and British speakers

Realisation	**L2 Thai learners**		**British speakers**	
	Frequency	**%**	**Frequency**	**%**
[z]	388	21.6	668	92.8
[s]	1407	78.2	52	7.2
[f]	1	0.1	-	-
[ɕ]	1	0.1	-	-
[ʃ]	1	0.1	-	-
[θ]	2	0.1	-	-
Total	1800	100	720	100

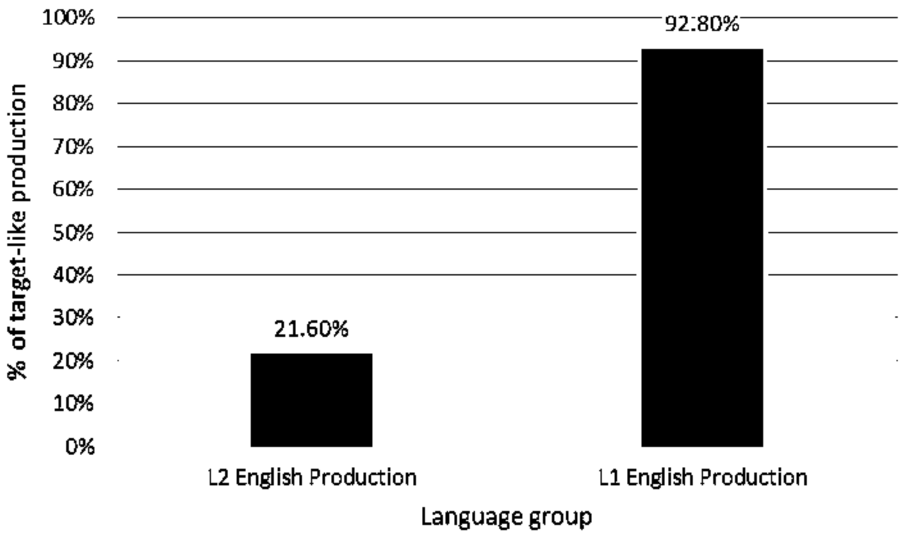

Figure 13. L2 English /z/ productions deemed target-like in the two groups of speakers

The GLMM results (Table 30) looking at sociolinguistic factors showed that the ratio of L2 /z/ production that was deemed target-like was significantly lower for male speakers compared to female speakers (b = -2.67, SE = 1.13, p < 0.01) and for high-frequency words (b = -0.30, SE = 0.09, p < 0.01) but higher in ideal L2 self (b = 3.10, SE = 0.75, p < 0.01) and LOR (b = 0.07, SE = 0.04, p < 0.05). The ought-to L2 self had potential to be significantly negatively correlated to L2 production that was deemed target-like (p = 0.07). Tukey's HSD post-hoc test showed that the proportion of L2 /z/ production that was deemed target-like was higher in the back high vowel context as compared to the other three vowel contexts (b = 2.23, SE = 0.62, p < 0.01 for back mid to low vowel; b = 1.64, SE = 0.43, p < 0.01 for front high vowel; b = 3.41, SE = 0.66, p < 0.01 for front low vowel), as well as for the front high vowel compared to front low vowel contexts (b = 1.77, SE = 0.49, p < 0.01). No significant differences were found in the back mid to low context as compared to front high vowel context (p = 0.23) although there was a potential for the back mid to low vowel context to be more target-like than the front to low vowel context (p = 0.06). Figure 14, Figure 15, Figure 16, Figure 17, Figure 18 show the relationships between L2 English /z/ production that was deemed target-like and gender, word frequency, ideal L2 self, LOR and vowel context, respectively. It is surprising that the mid-ranges of the target-like production which was correlated to word frequency and LOR were low.

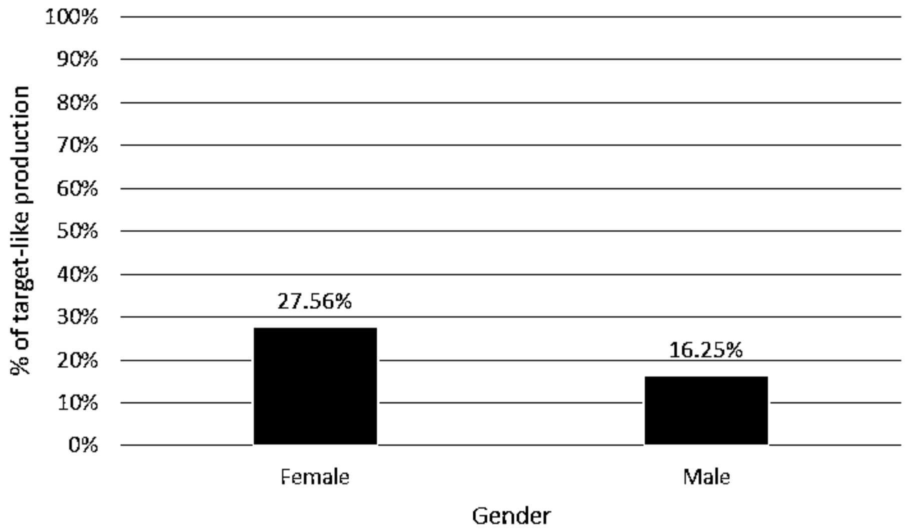

Figure 14. Relationship between L2 English /z/ productions that were deemed target-like and gender

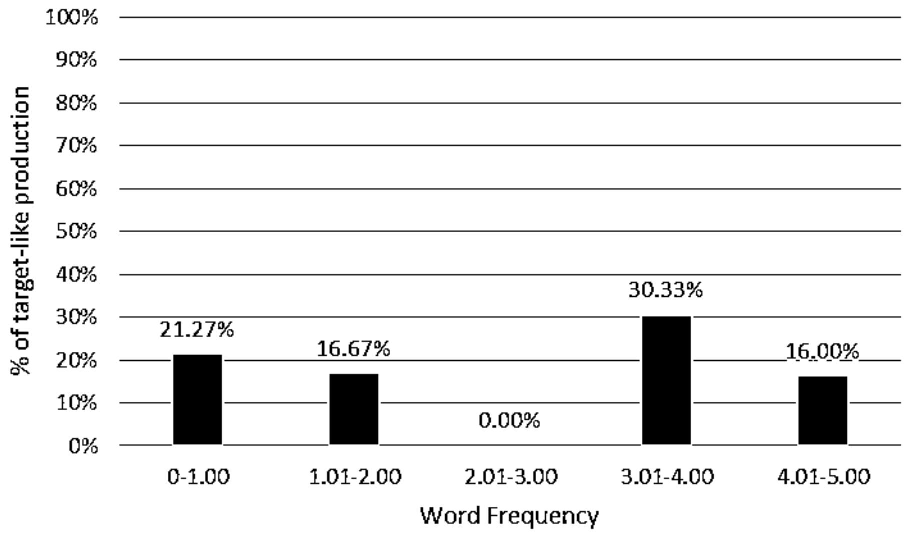

Figure 15. Relationship between L2 English /z/ productions deemed target-like and word frequency

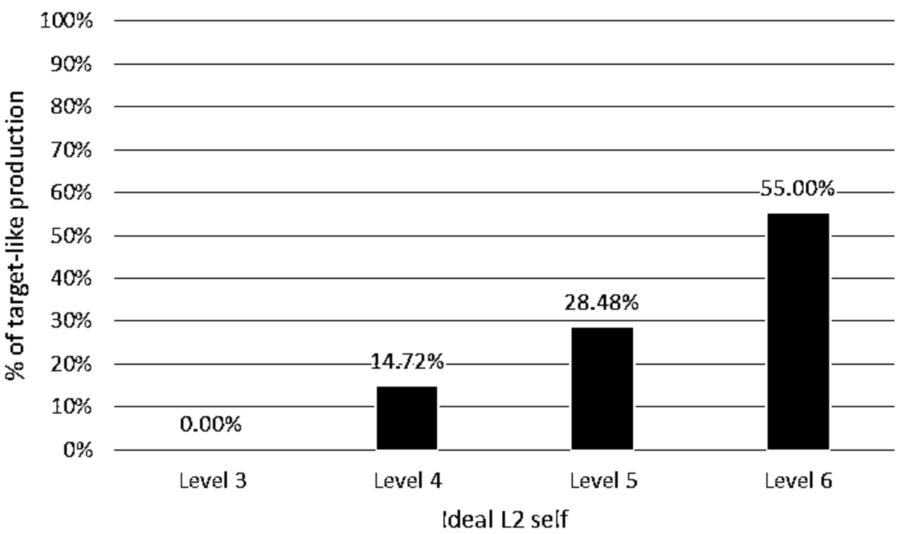

Figure 16. Relationship between L2 English /z/ productions deemed target-like and ideal L2 self

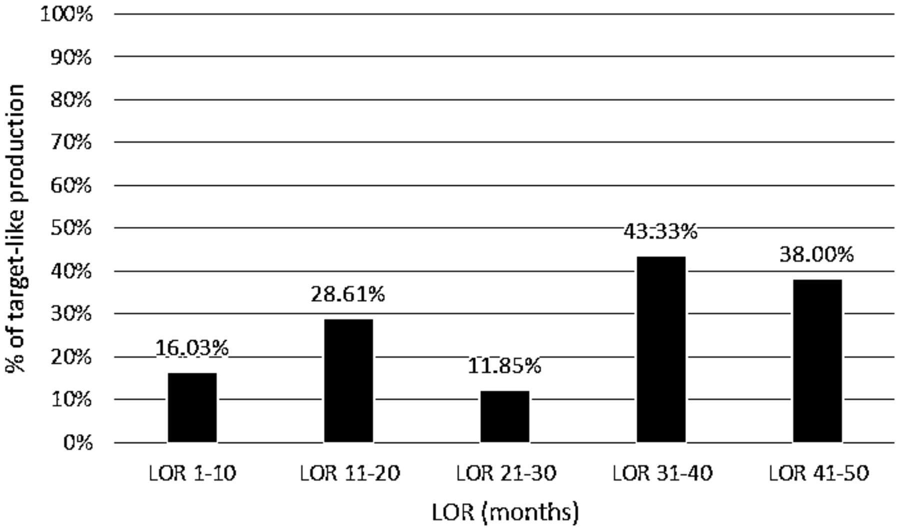

Figure 17. Relationship between L2 English /z/ productions deemed target-like and LOR

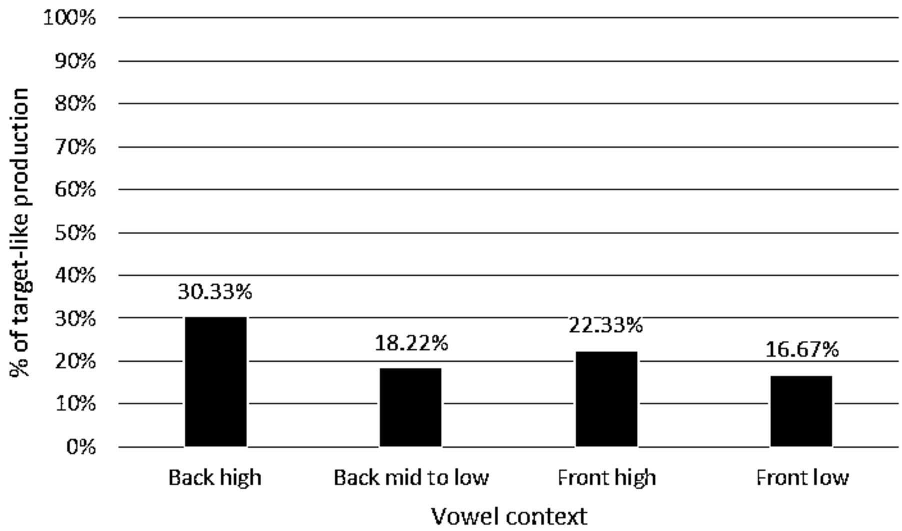

Figure 18. Relationship between L2 English /z/ productions deemed target-like and vowel context

Table 29. Estimates for intercept and one language group from GLMM model for impressionistic study of /z/

	Estimate	**Std. Error**	**z-value**	**Pr(>|z|)**
(Intercept)	3.9955	0.7696	5.192	0.000
L2 English	-7.1987	0.8856	-8.128	0.000

Table 30. Estimates for intercept and factors from GLMM model for impressionistic study of /z/

	Estimate	**Std. Error**	**z-value**	**Pr(>|z|)**
(Intercept)	-8.03764	4.94727	-1.625	0.0521175
Vowel (back mid to low)	**-2.23807**	**0.61541**	**-3.637**	**0.000138**
Vowel (front high)	**-1.64068**	**0.42831**	**-3.831**	**0.000064**
Vowel (front low)	**-3.4099**	**0.66107**	**-5.158**	**0.000000**
Male	**-2.6702**	**1.13561**	**-2.351**	**0.009353**
LOR	**0.07059**	**0.03902**	**1.809**	**0.0352015**
L2 exposure	-0.00228	0.01758	-0.13	0.448415
Frequency	**-0.29638**	**0.09077**	**-3.265**	**0.000547**
Ideal L2 self	**3.09815**	**0.75475**	**4.105**	**0.00002025**
Ought-to L2 self	-0.88602	0.61086	-1.45	0.0734685
L2 experience	-0.51075	0.57938	-0.882	0.189013
L2 anxiety	-0.50818	0.76613	-0.663	0.2535665

L2 English /ʃ/

Table 31 shows that most L2 English /ʃ/ tokens were deemed target-like in the production of Thai learners (93.56%). The GLMM (Table 32) showed that there were no significant differences in the number of productions that were deemed target-like between L2 Thai learners and native speakers of the L2 (p = 0.50). This suggests that L2 Thai learners had no difficulty producing L2 English /ʃ/ in initial position. This sound was also deemed to have been realised as [t͡ʃ, s, t͡ɕ, ɕ], respectively, for example /ʃɒp/ deemed to have been realised as [t͡ʃɒp], whereas in the production of English speakers, this sound was 100% deemed target-like (Figure 19).

Table 31. Impressionistic results of /ʃ/ production by L2 Thai learners and British speakers

Realisation	L2 Thai learners		British speakers	
	Frequency	%	Frequency	%
[ʃ]	1684	93.56	720	100
[tʃ]	72	4.00	-	-
[s]	40	2.22	-	-
[tɕ]	3	0.17	-	-
[ɕ]	1	0.06	-	-
Total	1800	100	720	100

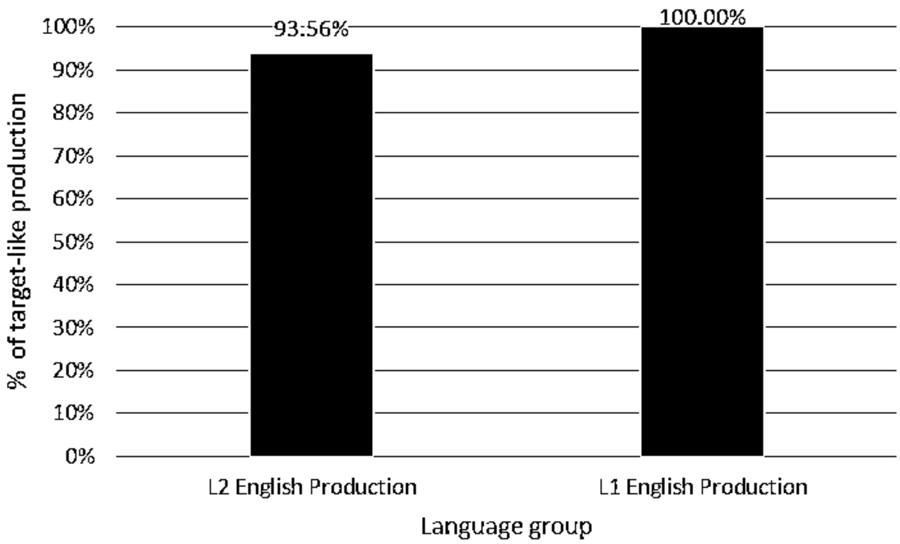

Figure 19. L2 English /ʃ/ productions deemed target-like in the two groups of speakers

In terms of sociolinguistic factors, the GLMM (Table 33) showed that the proportion of L2 /ʃ/ productions that were deemed target-like was lower when LOR (β = -0.06, *SE* = 0.02, p < 0.01) and L2 experience (β = -0.97, *SE* = 0.49, p < 0.05) increased but higher with an increase in word frequency (β = 0.00, *SE* = 0.00, p < 0.01) and in ideal L2 self (β = 1.24, *SE* = 0.51, p < 0.01). Ought-to L2 self had potential to be negatively correlated to L2 production that was deemed target-like (p = 0.08). Tukey's HSD post-hoc test showed that when the proportion of L2 /ʃ/ productions that were deemed target-like was higher in the back mid to low vowel context as compared to front low vowel context (β = 1.41, *SE* = 0.31, p < 0.01) and in the back high vowel context as compared to front low vowel context (β = 1.09, *SE* = 0.47, p < 0.05). The same applied to the back mid to low vowel context as compared to front high vowel context (p = 0.05) and the front high vowel context as compared to front low vowel context (p = 0.06). There was no significance difference in the target-like realisations of L2 /ʃ/ in the back high vowel context as compared to back mid to low vowel context (p = 0.46), and in the back high vowel context as compared to the front high vowel context (p = 0.40). Figure 20, Figure 21, Figure 22, Figure 23 and Figure 24 show the relationship between L2 /ʃ/ production that was deemed target-like and vowel context, LOR, word frequency, ideal L2 self and L2 experience, respectively.

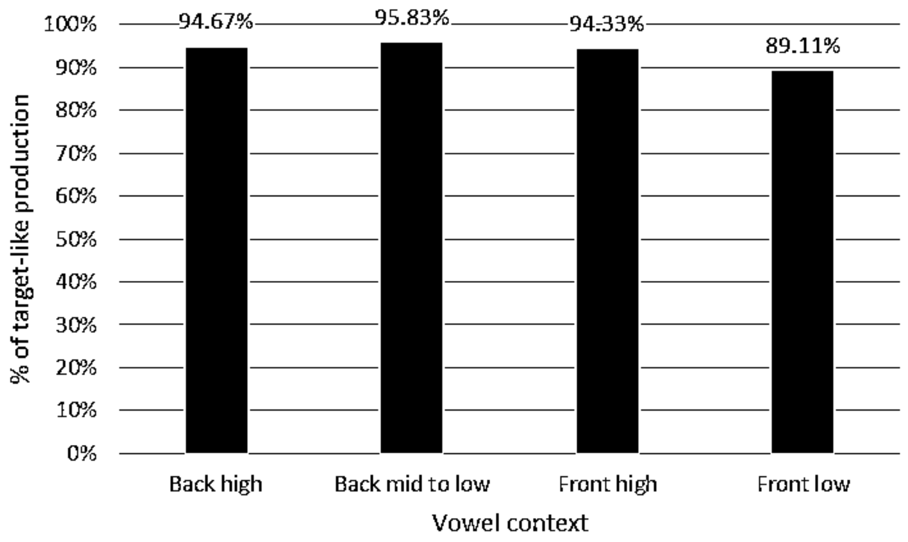

Figure 20. Relationship between L2 English /ʃ/ productions deemed target-like and vowel contexts

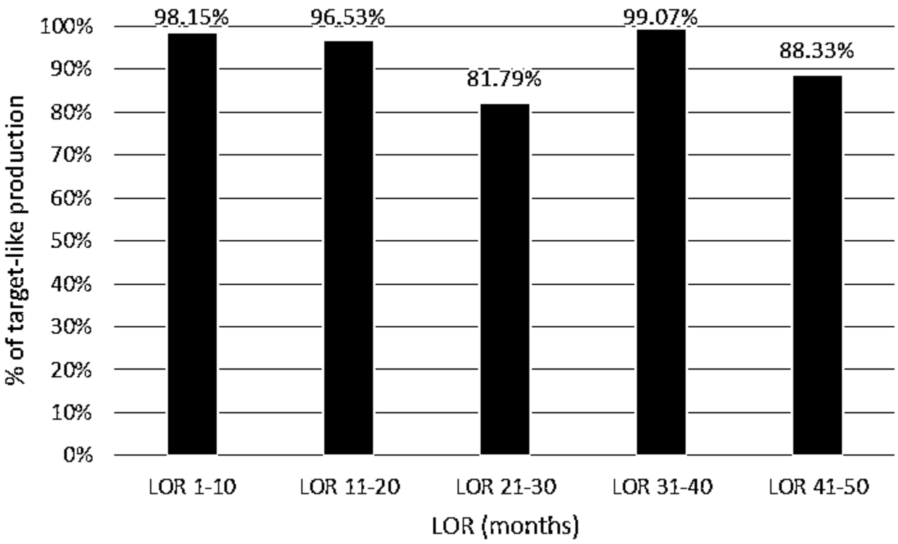

Figure 21. Relationship between L2 English /ʃ/ productions deemed target-like and LOR

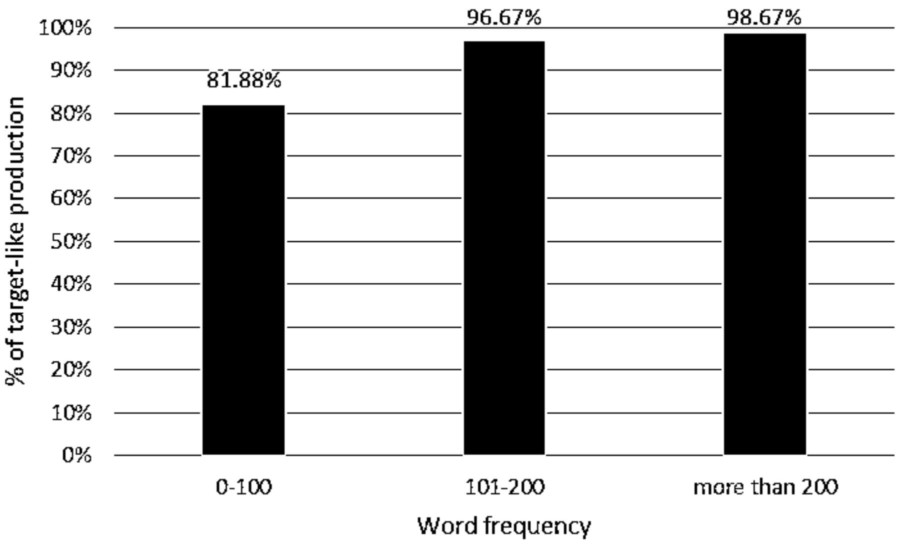

Figure 22. Relationship between L2 English /ʃ/ productions deemed target-like and word frequency

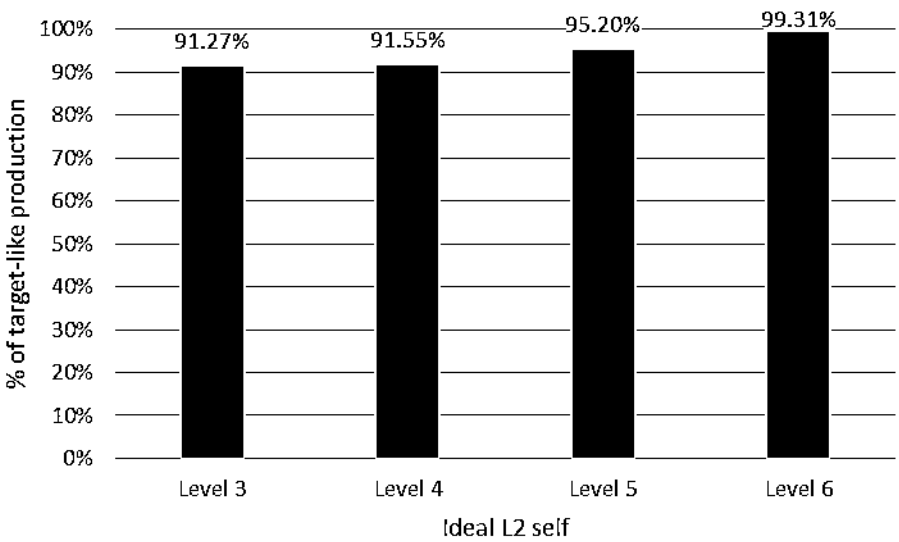

Figure 23: Relationship between L2 English /ʃ/ productions deemed target-like and ideal L2 self

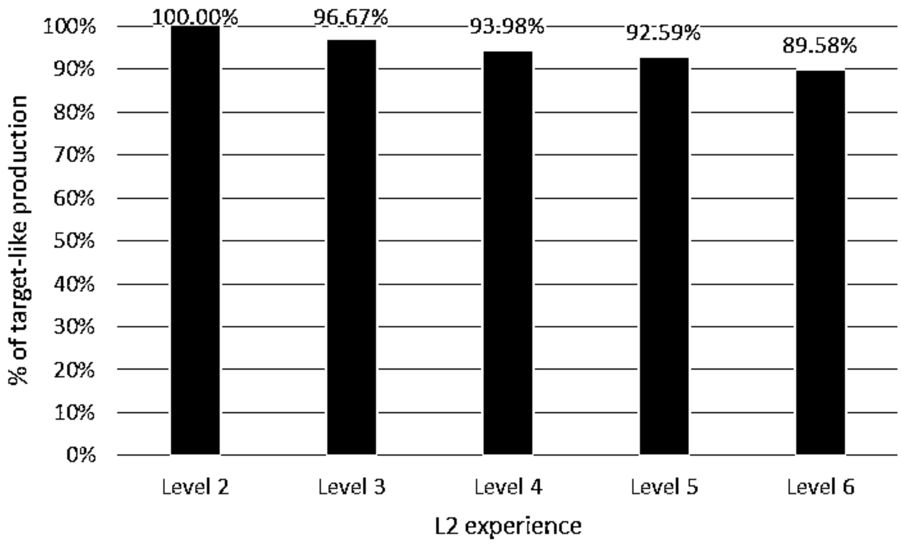

Figure 24: Relationship between L2 English /ʃ/ productions deemed target-like and L2 experience

Table 32. Estimates for intercept and one language group from GLMM model for impressionistic study of /ʃ/

	Estimate	**Std. Error**	**z-value**	**Pr(>|z|)**
(Intercept)	24.33	6513.5	0.004	0.4985
L2 English	-19.31	6513.5	-0.003	0.499

Table 33. Estimates for intercept and factors from GLMM model for impressionistic study of /ʃ/

	Estimate	**Std. Error**	**z-value**	**Pr(>|z|)**
(Intercept)	**6.961364**	**2.991164**	**2.327**	**0.009975**
Vowel (back mid to low)	0.315819	0.482543	0.654	0.2564
Vowel (front high)	-0.43248	0.477349	-0.906	0.182465
Vowel (front low)	-1.09128	0.465488	-2.344	0.04453
Male	0.358202	0.69387	0.516	0.302845
LOR	**-0.06163**	**0.023537**	**-2.618**	**0.004415**
L2 exposure	0.008393	0.010308	0.814	0.20777
Frequency	**0.000523**	**0.000196**	**2.672**	**0.003775**
Ideal L2 self	**1.238343**	**0.510724**	**2.425**	**0.00766**
Ought-to L2 self	-0.59343	0.413874	-1.434	0.075805
L2 experience	**-0.97052**	**0.492482**	**-1.971**	**0.02438**
L2 anxiety	-0.22761	0.411622	-0.553	0.290145

3.3.3 Main results from semi-structured interviews

The interviews revealed some interesting results regarding the L2 Thai learners' attitudes towards having a Thai accent when speaking English. Most L2 Thai learners saw communication as the main goal of speaking English and did not mind speaking with a Thai accent. Many of them did not wish to have a British accent in their English speech. The following quotations are illustrative of their views regarding accented English:

> "I do not want to have a British accent. I want … just to say what I would like to convey and they understand. It is okay to have a Thai accent." (Participant 100103)

> "It is fine to speak English with a Thai accent. I just would like to feel like … umm for Thai accent, with this age, of course there is a Thai accent in my speech, but I would like to speak fluently and they understand what I am communicating. At the moment, I am not very fluent. I can communicate but it is not like speaking in Thai. I would like to say it once. Sometimes, especially in complex sentences, we have to explain indirectly as I do not know what words to use." (Participant 100107)

> "In my opinion, having a British accent when speaking English is good, but not necessary. It is more important to communicate and understand. It is okay to speak English with a Thai accent. We were not born here – it is impossible for us to speak English with a British accent." (Participant 100114)

> "I have no problem speaking English with a Thai accent. Maybe it is also because my colleagues in my lab are used to the Thai accent, so no problem. When I have a problem in pronunciation, especially when talking to other non-native English speakers, such as Indians, I might need to spell words, but with other British speakers, I do not need to do that, not because I speak well, but British speakers understand me. I do not want my Thai accent to be gone. It is not necessary to change the accent, having a Thai accent is fine." (Participant 100122)

On the other hand, some of the L2 Thai learners expressed an interest in having a British accent when speaking English, but knew it was unrealistic and did not mind having their native Thai accent, as illustrated by some of their responses:

> "I would like to have a British accent, but when speaking with a Thai accent, they understand me." (Participant 100126)

> "I would like to have a British accent, but do not feel ashamed about having a Thai accent." (Participant 100127)

> "Of course I would like to have a British accent, but I know this is impossible. This is the ideal dream, but I can accept my own accent." (Participant 100116)

3.4 Discussion

Before discussing the main results, a summary of the results is provided here.

L2 Thai learners had no difficulty producing the only two shared sounds tested, /f/ and /s/, or the non-shared sound /ʃ/. However all the other non-shared English sounds, namely /v, θ, ð, z/, were difficult for them to produce. Regarding sociolinguistic factors, ideal L2 self was found to be positively related with the target-like production of /v, θ, z, ʃ/ whereas L2 anxiety was found to be negatively related to the target-like production of /v, θ/. Being male as compared to female was negatively correlated to the target-like production of /v, z/. Although LOR was found to be positively related to the target-like production of /ð, z/, it was found to be negatively correlated to the target-like production of /ʃ/. L2 English experience was found to be negatively related to the target-like production of shared /s/ and non-shared /ʃ/. Although the frequency of words was found to be negatively correlated to the target-like production of /z/, it was found to be positively related to target-like /ʃ/ production. In terms of vowel context, whereas the back high vowel context as compared to front low vowel context was negatively related to the target-like production of /s/, it was found to be positively related to the target-like production of /z/ as compared to the other three vowel contexts and of /ʃ/ as compared to the front low vowel context. The back mid to low vowel context as compared to front low vowel context was also positively related to the target-like production of /ʃ/.

3.4.1 Discussion regarding shared fricatives

The impressionistic results on shared fricatives show that L2 English /f/ production exhibited a high percentage of productions that were deemed target-like (99.39%) and there was no significant difference in /f/ accuracy across all language groups, signifying that L2 learners had no difficulty producing this shared L2 sound. This result supports the results of Chunsuvimol and Ronakiat

(2000) and Kanokpermpoon (2004) on the production of L2 English /f/ by L2 Thai learners, namely that they had no difficulty producing this sound in initial position.

Moving on to L2 English /s/, even though the percentage of productions that were deemed target-like by L2 speakers was lower for this shared sound than when they produced L2 English /f/, the percentage of production that was deemed target-like was high and there was no difference in accuracy between the groups of L2 Thai learners and native English speakers. Thus, from an impressionistic perspective, it seems that L2 learners find L2 sounds that also exist in their L1 sound system easy to produce, supporting findings of previous studies (e.g. Major and Kim, 1999; Chunsuvimol and Ronakiat, 2000; Kitikanan and Al-Tamimi, 2012). The sociolinguistic results suggest that the proportion of target-like L2 English /s/ production is negatively correlated with L2 English exposure; this seems to contrast with previous findings (Flege *et al.*, 2006; Stevens, 2011), but may be due to the already high target-like figures across the groups, leaving little room for differences. These results might also be due to the fact that the subjects in this study were students and their main linguistic activities while residing in the UK were writing and reading, rather than speaking and listening. If attention is not paid to the latter two skills, the production aspects of L2 English speech to stay similar to the level as when they just started their study in the L2 country or even become slightly less target-like. It was also found that target-like L2 English /s/ production is negatively correlated with the back high vowel context as compared with the front low vowel context. The results of L2 English /f/ and /s/ in this type of analysis confirm the CAH-based hypothesis, which states that similar sounds are easy to learn.

3.4.2 Discussion regarding non-shared fricatives

The impressionistic analysis of non-shared fricatives showed that most L2 non-shared English fricatives, /v, θ, ð, z/ had a low proportion of productions that were deemed target-like, and these were statistically lower than those produced by L1 speakers. Most results on substitutions here support previous studies in the literature. Starting with L2 English /v/, most productions were deemed to have been realised as [w], which is consistent with the findings from previous studies on L2 English /v/ production by L2 Thai learners (Chunsuvimol and Ronakiat, 2000; Chunsuvimol and Ronakiat, 2001). For L2 English /θ/, most realisations by

Thai learners were produced as [t], consistent with the findings of studies on L2 English /θ/ production by Thai learners (Brière and Chiachanpong, 1980; Wester *et al.*, 2007; Burkardt, 2008). In fact [tʰ] can be a variant for native English /θ/ (Stuart-Smith, 2004), but the reason why L2 Thai learners used [t] as the main substitution for /θ/ rather than [tʰ] might be that they see the need to maintain a contrast between L2 English /θ/ and /t/; the Thai sound system contains the phonemes /t/ and /tʰ/ and thus they might have chosen [tʰ] for native English /t/ and [t] for native English /θ/ although this cannot be verified with the current data. For L2 English /ð/, [d] was the main replacement, which is also consistent with previous literature (Brière and Chiachanpong, 1980; Wester *et al.*, 2007; Burkardt, 2008). [d] is also an acceptable variant for native English /ð/ (Labov, 1969) – it is possible that besides using [d] for English /ð/ due to the nonexistence of /ð/ in their Thai phonological system, the L2 Thai learners used this sound for substitution due to the input from native speakers of L2. This study also found that L2 English /θ/ had a higher percentage of target-like realisations than L2 English /ð/, which is in contrast to some studies on L2 English interdental fricative learning (e.g. Syed, 2013). For L2 English /z/, the result that the most frequent substitution for this production was [s] is consistent with previous studies (Brière and Chiachanpong, 1980; Charmikorn, 1988). Similar to the account for [d] as a substitution for L2 English /ð/, the main substitution of L2 English /z/ with [s] might also have occurred due to input from native speakers commonly having a wholly or partially devoiced /z/ (Smith, 1997). The main results for the L2 English fricatives /v, θ, ð, z/ can be accounted for by the non-existence of these L2 sounds as phonemes in the native Thai phonological system, supporting the hypotheses predicted by CAH (Lado, 1957).

L2 English /ʃ/ production had a high percentage of productions that were deemed target-like, i.e. which did not differ from native English production. This might be due to the fact that native Thai /t͡ɕʰ/ and native English /ʃ/ tend to occur in the same place of articulation. As can be seen from the work of Brière and Chiachanpong (1980), who used [t͡ʃ] to represent /t͡ɕʰ/ or 'ช' in Thai, it is possible that English /ʃ/ and Thai /t͡ɕʰ/ differ only in the manner of articulation in that the Thai phoneme is an affricate and the English phoneme is a fricative. The reason why some other researchers used [t͡ɕʰ] instead of [t͡ʃ] might be that they wish to differentiate the Thai phone from the English phone as native English /ʃ/ is typically made with lip rounding whereas native Thai [t͡ɕʰ] is typically made with lip spreading. While L2 English /ʃ/ was target-like based on its auditory impression, articulatory and acoustic analysis might help reveal if it was produced with lip rounding as in native English /ʃ/ or lip spreading as in native Thai [t͡ɕʰ]. The results of L2 English /ʃ/ disconfirmed CAH-based hypotheses that this sound would be difficult to produce due to its non-existence in the Thai sound system.

Regarding the sociolinguistic perspective, being female was correlated positively with the production of L2 English /v/ and /z/, supporting the findings of other studies that females outperforms males in language performance (e.g. Asher and García, 1969; Piske *et al.*, 2001; Díaz-Campos, 2004; Major, 2004). This suggests that female L2 Thai learners were more sensitive to the production of L2 English /v/ and /z/ as opposed to male L2 Thai learners. This might also be because Thailand is a patriarchal society and using English is considered a female activity, with most students majoring in English in Thailand being female (McKenzie *et al.*, 2015).

Moreover, three motivational factors were also found to play a role in target-like production. The first was the ideal L2 self, which was always found to be positively correlated to productions of L2 English /v, θ, z, ʃ/ that were deemed target-like. This might suggest that the ideal L2 self plays a major role in L2 speech, which is in line with the results of previous studies (e.g. Ryan, 2009; Taguchi *et al.*, 2009; Csizér and Lukács, 2010; Ghapanchi *et al.*, 2011; Ghonsooly and Shirvan, 2011; Apple *et al.*, 2012). The results here are also consistent with those of positive correlations between attitudes and English proficiency in subjects in the US, i.e. that the greater the L2 learner's sense of group belonging with native speakers of L2, the higher their L2 proficiency (Spolsky, 1969; Oller *et al.*, 1977). According to Ryan (2008), whose study was carried out with Japanese participants in Japan studying English as a foreign language, the ideal L2 self is also a core component of learners' attitudes towards language, affecting their efforts to learn.

One reason why ideal L2 self was a more consistent factor in target-like attainment than LOR and AOA, which are normally found to play a major role in L2 contexts, might be due to the difference in contexts; i.e., the participants in most previous studies on L2 speech acquisition were immigrants and thus expected to live in the L2 country for a long time. In this study, the participants were people who were living in the L2 country for a relatively short duration and had experience of using L2 English as a foreign language in the L1 country (Thailand) for a long period of time. Their chance of exposure to native English speakers when living in their home country was much lower than that of immigrants resident in the L2 country in previous L2 speech studies. Most participants in this case also expected to go back to live in their native country when they had completed their studies. Moreover, as students, the main activities in which the Thai learners engaged in in the L2 were reading and writing. Thus the opportunities to converse with native speakers of L2 were low. These results are in line with those of Simon and D'Hulster (2012), who suggest that motivation and interest in language learning are influential in the success of L2 pronunciation by those learners who learn English as a foreign language. The results of this study show the importance of one's internal drive in L2 sound learning, with the ideal L2 self being the most outstanding factor related to the production of L2 non-shared sounds.

This study found that L2 experience was only negatively related to productions of /ʃ/ that were deemed target-like but it had no relationship with the target-like productions of the other fricatives. As this factor is engaging with the actual language learning process (Dörnyei, 2009), this result suggested that the production of L2 English /ʃ/ of Thai learners was influenced by situational factors such as the teaching materials, the peer group, the L2 teacher, whereas these factors did not improve the productions of the other fricatives. The other aspect was L2 anxiety, which was always found to be negatively related to productions that were deemed target-like of L2 English /θ, v/, consistent with previous findings that L2 anxiety seems to decrease language proficiency (e.g. MacIntyre and Gardner, 1991; Kitano, 2001; Alemi *et al.*, 2011; Zhang, 2013). Feelings of panic, nervousness and confusion might result in production that was deemed non-target-like of these two sounds.

Some factors did not show clear patterns. Whereas high word frequency was correlated negatively with productions of L2 English /z/ that were deemed non-target-like, it was related positively to L2 English /ʃ/ productions that were deemed target-like. The result that word frequency showed a positive relation for L2 English /ʃ/ is consistent with many previous studies (e.g. Akamatsu, 2002; Levi *et* *al.*, 2007; Drummond, 2010). From the result of L2 English /z/, this sound was mostly replaced by [s] which is also a common variant of /z/ in the production of native speakers of English. Thus it is possible that Thai learners had low number of target-like production of L2 English /z/ due to the input from English native speakers. Similarly, for vowel contexts, there was no clear pattern – different vowel contexts were correlated with different L2 English fricatives, i.e. for L2 English /z/, the high back vowel (when compared to other vowel contexts) and the front high vowel (when compared to front low vowel) were positively related to productions that were deemed target-like; however, for L2 English /ʃ/, the back mid to low vowel (in contrast to the front low vowel) and back high vowel contexts (in contrast to the front low vowel) were related positively to production that was deemed target-like. LOR was found to be related negatively to production of L2 English /ʃ/ that was deemed target-like but correlated positively to the production of L2 English /ð, z/ that was deemed target-like. The latter result is in agreement with findings from previous literature (e.g. Asher and García, 1969; Purcell and Suter, 1980; Flege *et al.*, 1995b; Drummond, 2010).

3.5 Summary

This chapter investigated L2 English fricative production by Thai learners with a focus on the presence or absence of target-like production and how this is influenced by the phonological inventory of the two languages as well as various sociolinguistic factors. An impressionistic analysis of shared L2 fricatives suggested that their production was deemed target-like and showed no significant difference in their production across native English, native Thai and L2 English, confirming CAH hypotheses. Most results on non-shared L2 fricatives, except for L2 English /ʃ/, also confirmed CAH hypotheses; hence, based on this type of analysis, CAH only failed to predict the results of L2 English /ʃ/.

Given the caveats around impressionistic analysis and a judgment of target-likeness that is based on broad transcription of the participants' speech by a phonetically trained yet non-native speaker of the L2, the next chapter explores the identification of these sounds by native speakers of the L2. The aim is to explore the extent to which native speaker judgements are consistent with the impressionistic results in this chapter. No previous studies have been dedicated to examining L2 English fricative production by L2 Thai learners as perceived by a group of L2 native speakers. Hence, this is the first study to ask a group of native speakers of English, specifically British speakers of various ages and from different regional backgrounds and fields of study, to make judgements on the sounds they perceive by identifying words with target L2 English fricatives as produced by Thai learners.

Chapter 4. Sound identification analysis of L2 fricatives

4.1 Introduction

While the impressionistic analysis was carried out by the author, who is a native speaker of Thai, another measure was planned in order to further probe the extent to which Thai learners produce target-like fricatives. A sound identification task was designed in which native English listeners heard the onset fricative and part of the following vowel from a target English word as produced by the Thai participants in this study, and identified the word from a minimal set with word-initial fricatives. In this analysis, the term 'correct' for sound identification was used when the token was identified as falling in the aimed-for category. The aim was to find out if native listeners identify the fricatives intended by Thai learners, which also gives a rough measure of intelligibility. Only one word from the front high vowel context in each fricative was used as this context has the most similar articulatory environment between native Thai and native English to keep duration of the experiment sufficiently short. In past studies on L2 English fricative production by L2 Thai learners, the results have been based on the sound judgements of one or two phoneticians or the authors (Richards, 1966; Brière and Chiachanpong, 1980; Charmikorn, 1988; Pansottee, 1992; Chunsuvimol and Ronakiat, 2000; Chunsuvimol and Ronakiat, 2001; Burkardt, 2008; Roengpitya, 2011) – some of whom were native speakers of Thai. To the best of my knowledge, the present study is the first in on the topic of English fricative production by L2 Thai learners to also ask a group of native listeners of English to identify the word they hear.

Native listeners of English were asked to identify the sounds they thought they heard when listening to the same stimuli as used for the impressionist analysis whose results were presented in Chapter 3. Instead of transcribing words, listeners had to choose the relevant target word. Based on the hypotheses from CAH, the easy production of the shared fricatives /f, s/ will easy to identify correctly by native-speaking English listeners. For the other five non-shared fricatives /v, θ, ð, z, ʃ/, CAH predicts that the percentage of correct identification will be low. The results of this experiment are intended to provide another perspective on the degree of target-likeness in L2 production.

4.2 Methodology

4.2.1 Listeners

Ten female British native listeners took part in this sound identification task. All the listeners were students at Newcastle University at the time of the study. Most but not all of them (80%) had some degree of phonetic training as they were studying for a degree in speech and language therapy. All of them, except the last listener, were born in the UK. Even though the last listener was born in the Sudan, she had moved to Ireland at the age of one, had lived in England since the age of three and had used English as the main language at home; thus she was considered a British English native speaker. The listeners were from various regional birth places, of different ages and had different dialects to reflect the real context of the L2 English environment. The ages of the listeners ranged from 19 to 34 years at the time of the experiment (*M* = 23.1, *SD* = 5.17). None of listeners had a background in Thai, nor did they report having speech or hearing disorders. Table 34 presents information on the British listeners in the sound identification task.

Table 34. British listeners in the sound identification task

Code	Age	Birthplace	Place of residence for most of life	Programme of study
400101	19	Middlesbrough	Lancaster	Speech and Language Therapy
400102	22	Nottingham	North England	Speech and Language Therapy
400103	19	Southampton	Southampton	Speech and Language Therapy
400104	34	Wales	Newcastle	Education
400105	20	Hampshire	Hampshire	Speech and Language Therapy
400106	20	Nottingham	Nottingham	Speech and Language Therapy
400107	21	Leicester	Leicester	Speech and Language Therapy
400108	31	Glasgow	Glasgow	Speech and Language Therapy
400109	23	Macclesfield	Macclesfield	Speech and Language Therapy
400110	22	Sudan	Birmingham	Linguistics

4.2.2 Stimuli

The stimuli for this experiment were the native English, the native Thai and the L2 English words from the production task presented in Chapter Three. As stated, the front high vowel context is the environment in which the following vowels in Thai and English are the most similar in terms of frontness and lip spreading. One target English word with an /i/ vowel that was used in the production experiment was chosen for each target fricative: ‘feel’, ‘veal’, ‘thief’, ‘these’, ‘seat’, ‘zeal’ and ‘sheet’. For Thai, the words were as follows: /fîik/ ‘conceal’ and /sîik/ ‘piece’. Care was taken in word selection to avoid words ending with a nasal or approximant.[14] However, some words, such as ‘feel’ and ‘veal’, were chosen despite ending with an approximant because their contexts of occurrences were more comparable. For each fricative 10% of the productions in the front high vowel context for the two language groups (three language groups for shared fricatives) were chosen as stimuli. To generate a randomised list, all productions of each target fricative were ordered in Excel and the selected productions were taken from the first 10% of the largest number using the ‘RAND’ (random) function regardless of their realisations and the gender of speakers. The number of stimuli that each listener heard was 490 ([159 stimuli × 3 times] + 13 stimuli for the training phase). Table 35 shows the number of stimuli related to each target fricative in each language group.

Table 35. Number of stimuli for each target fricative

Target word	Native Thai	Native English	L2 English
/f/	6	6	15
/s/	6	6	15
/v/	-	6	15
/θ/	-	6	15
/ð/	-	6	15
/z/	-	6	15
/ʃ/	-	6	15

The stimuli were extracted from the original sound files in Praat. The beginning of the stimulus was defined as the starting point of the target fricative, while the ending of the stimulus was defined as an interval ending at 50 ms into the vowel following the target fricative. The ending was chosen to enhance the perceptual salience of the stimulus as a fricative; that is, stop and affricate realisations are difficult to hear in isolation. The selected portion was extracted and windowed by a parabolic function and intensity was normalised to 65 dB.[15] In some previous studies (e.g. Flege and Port, 1981; Bohn and Flege, 1992), listeners heard stimuli as whole words; however, their findings might have an effect of lexical bias (Piske *et al.*, 2002). In other previous studies (e.g. Flege, 1992), only a portion of the

[14] A nasal consonant might lower formants in general whereas an approximant might make the consonant vowel-like and might result in difficulty in segmenting.
[15] This parabolic function produced the most comparable length to the original extracted sound but allowed smoothing of the edges as to not have any clipped productions.

target sound was used, which might lessen the degree of sound identification of the target sound because of the lack of temporal cues (Bond, 1976). Having a full portion of the fricatives and part of the following vowel lessened the likelihood of listeners judging the stimuli on other sounds produced in a non-native manner rather than the target initial sounds which were the focus of this experiment. Figure 25 shows the boundary of sound extraction, and Figure 26 illustrates the actual extracted sound. Each stimulus was sampled at 44 kHz, bin mono channel (16-bit quantisation).

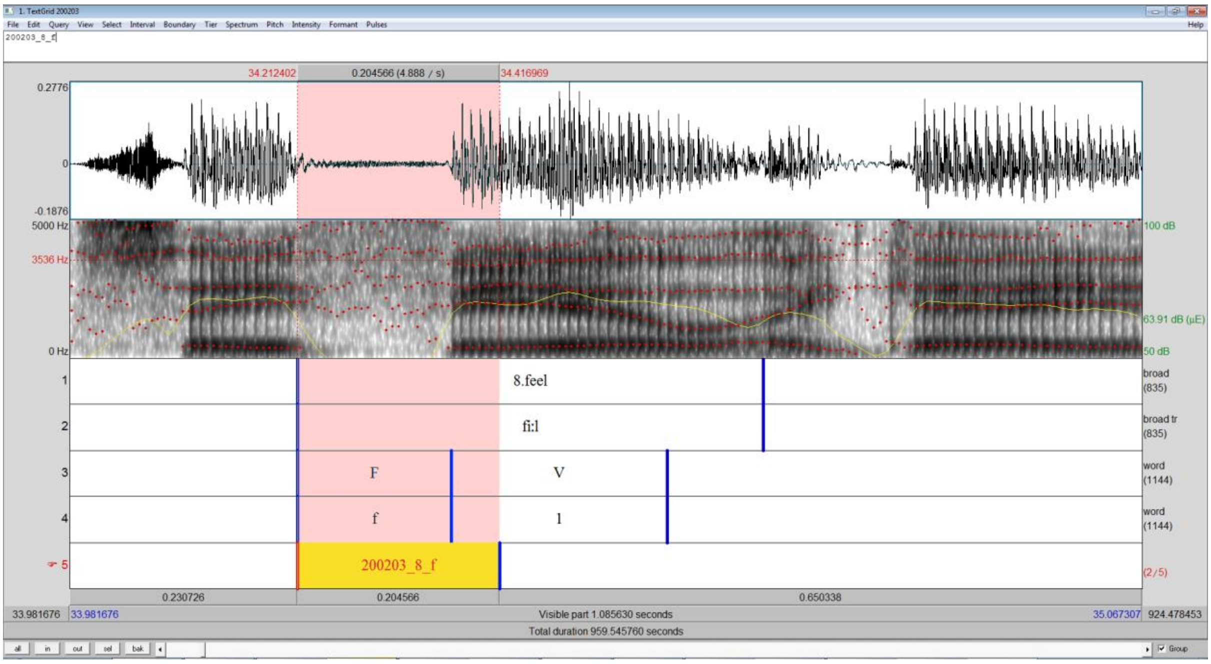

Figure 25. Stimuli extraction with full initial part of the consonant and 50 ms of the following vowel

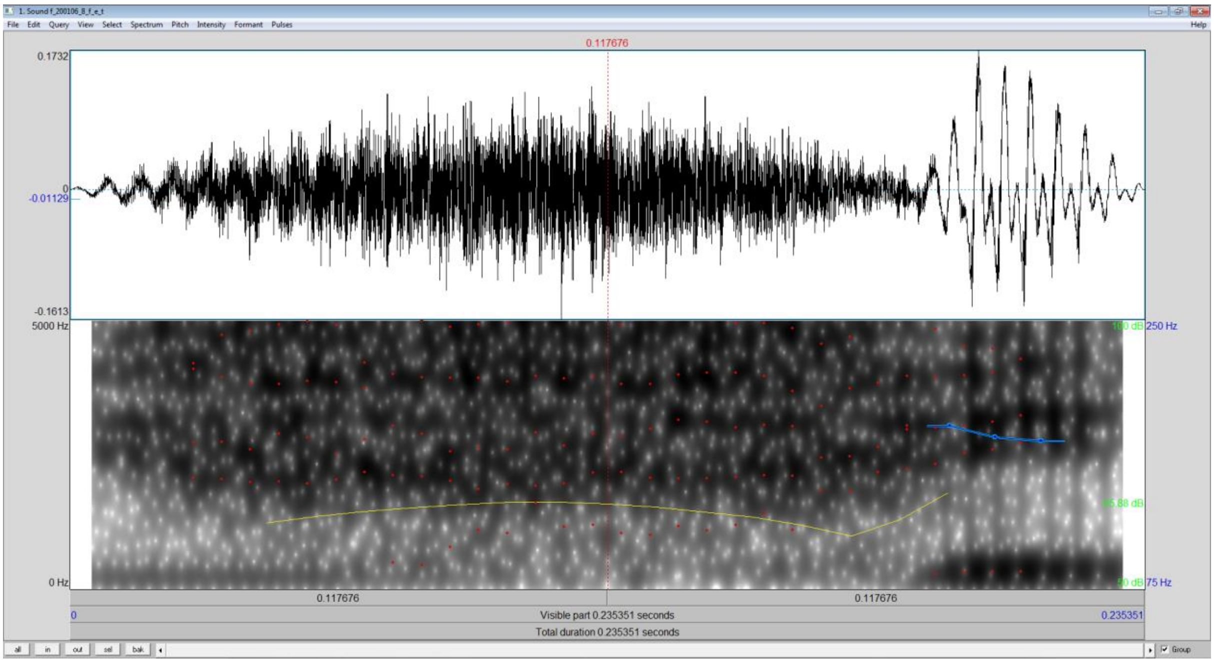

Figure 26: Actual extracted sound with full initial part of the consonant and 50ms of the following vowel

4.2.3 Experimental design

Each listener sat at their own desk with a computer and listened to the stimuli through headphones in a laboratory in the Speech and Language Sciences department, Newcastle University. The headphones were Sennheiser PC 131 with 30 - 18000 Hz frequency response, also used in many other speech studies (e.g. Davis *et al.*, 2008; Beijer *et al.*, 2010). As this was a perceptual experiment in which each listener had their own headphones, several could participate in the experiment at the same time. The task was run using ExperimentMFC in Praat. A silence portion of 1.0 seconds was added before the start of the stimuli. ‘PermuteBalanced’ randomisation was used, with each stimulus occurring once in each block and in random order. The listeners were given the following statement: *At the beginning of each of the following slides, the first part of an English word will be played. Please identify that word from the options on the screen. You can replay the sound file as many times as you need*. In the training phase, listeners heard 13 stimuli. In the experimental phase, they heard 159 stimuli with three randomised repetitions, yielding 477 tokens. For both phases, before they clicked the answer, they could listen to a stimulus up to 100 times by clicking the ‘Replay’ button. They also had a break after every 100 stimuli. They saw a screen with a question asking ‘Which word do you think the first part you heard is from?’ They had 11 options to choose from: ‘feel’, ‘weep’, ‘deep’, ‘seat’, ‘thief’, ‘teeth’, ‘zeal’, ‘cheat’, ‘veal’, ‘these’ and ‘sheet’. In some previous studies (e.g. Flege *et al.*, 1995a), listeners were offered single sounds as options, such as ‘s’ or ‘f’ when the target sound was /θ/. There were two reasons for not following this procedure. First, in real conversation, listeners usually receive messages through words. Second, the author did not want listeners to have to resort to IPA transcription of the sounds in the options offered to allow for listeners from all regional variety backgrounds. Therefore, options were provided in words instead of single sounds. These selected words all contained a sound that was identified as a substitution of the target fricatives as produced by the L2 learners. As the listeners were asked to identify the word which they thought the first part was from, they were most likely to be able to identify these sounds as being the intended target fricatives or one of the substitutions. The approximate duration for this experiment was one hour and listeners were given £5 as a thank you gift. An example of the screen for this task is shown in Figure 27.

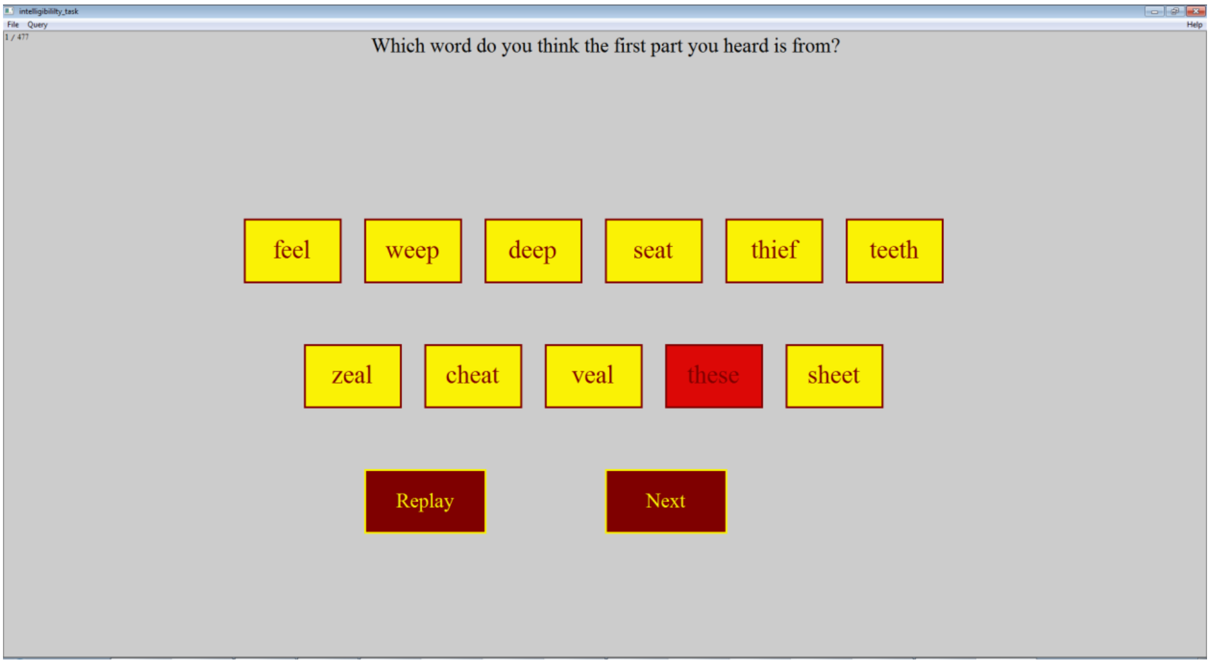

Figure 27. Example of screen of sound identification task

4.2.4 Data analysis

The main differences between the impressionistic analysis in Chapter Three and the sound identification task were the linguistic background of the listeners and the task requirements. It is hence interesting the compare the number of target-like realisations in Chapter Three with the number of correct identification in this chapter to see the effects of these two factors. Descriptive results were manipulated by running a Pivot Table in Microsoft Excel. To compare the individual sounds in the two sets of results, perceived realisations from the previous chapter are shown here together with the perceptual results by native speakers of English. In each table of percentages and frequencies, the realisations based on the impressionistic by the author are listed in the top row in square brackets, whereas the 11 options for each target fricative in this experiment are listed in the column on the left (e.g. Table 36).

All the perceptual results were transformed into d-prime (Abdi, 2007), a measure that reduces the bias in perceptual results. The target-like realisations from impressionistic analysis were classified as signal trials whereas non-target-like realisations from impressionistic analysis were classified as noise trials. The d-prime results were calculated from hit rate (number of target-like realisations that were identified as correct divided by total number of target-like realisations) and false alarm rates (number of non-target-like realisations that were identified as correct divided by total number of non-target-like realisations). When the accuracy is 100%, the d-prime value is 0.99 whereas when it is 0%, the d-prime value is 0.01%. When d-prime is extremely large, this correlates with high percentage accuracy whereas the lowest indicated low accuracy. The d-prime results will be called 'sensitivity' of the listeners' perception throughout this study. The low value of d-prime indicates the low ability to distinguish the target-like realisations (signals) from non-target-like ones (noise); hence the high value of d-prime indicates the high ability to distinguish the target-like realisations from non-target-like ones (Stanislaw and Todorov, 1999).

To determine whether the extent of correct sound identification of L2 production was significantly different from L1 production(s), LMMs were estimated using the *lme4* package (Bates *et al.*, 2014) in R (Team, 2013) based on d-prime results. The independent variable was language group (factor): native English, L2 English and native Thai (for shared fricatives). The dependent variable was d-prime score (interval). The random intercept was listener (factor). An example of the R code is as follows:

```
model1 <- lmer (dprime ~ language + (1|listener), data =
        data1.frame, REML = TRUE)
```

Tukey's HSD post-hoc tests using the *lsmeans* package in R statistical software (Lenth, 2014) were employed to identify significant differences between each pair of language groups based on the LMMs, coded as the following example:

```
lsmeans(model1, pairwise~language, adjust="tukey")
```

4.3 Results

4.3.1 Sound identification of shared fricatives

L2 English /f/

The descriptive results in Table 34 present a summary of perceptions of /f/ realisations produced by the three language groups based on the judgements of native listeners of English compared to the impressionistic analysis in Chapter Three (top row). It also shows that, unlike the results from the impressionistic analysis, in which all the stimuli for this shared fricative were deemed to have been realised as target-like, not all /f/ stimuli in all language groups were accurately identified as /f/ in the sound identification task; nevertheless, the percentages of correct identification for /f/ were high in the three language groups. The highest number of misidentifications of /f/ was [v] in all language groups. For native English /f/, listeners also misidentified as [θ, z, ð, ʃ], and native Thai /f/ was also incorrectly identified as [θ]. L2 English /f/ had patterns of identification rather similar to those of native English /f/, being misidentified as [θ, z, ð] in addition to [v]. When concentrating on the overall performance of [f] identification by native listeners and averaging the accuracy of L2 English [f] identification regardless of being target-like or non-target-like, the percentage of correct sound identification of /f/ was 82.89% which is high but lower than the percentage of target-like /f/ realisations by the author (100.00%) (see Figure 28).The results from d-prime shows that listeners were most sensitive to native Thai stimuli (M = 3.90, SD = 0.60), followed by native English (M = 3.83, SD = 0.81) and L2 English (M = 3.34, SD = 0.41) ones. Tukey's HSD post-hoc test based on d-prime results showed significantly higher sensitivity in the identification of /f/ for native English stimuli than for L2 English stimuli (b = 0.49, SE = 0.20, p < 0.05, also see Table 37). It also showed a significantly lower sensitivity in the identification of /f/ for L2 English stimuli than for native Thai stimuli (b = -0.55, SE = 0.20, p < 0.05, also see Table 37).

Table 36. A comparison of the author's transcription of /f/ tokens with native English listeners' identification of the same sounds in the sound ID task

/f/	Author's transcription					
Native listener perception	L2 English		Native English		Native Thai	
	[f]		[f]		[f]	
	Nb.	Nb.	Nb.	Nb.	Nb.	%
[f]	373	155	165	165	373	82.89
[w]	-	-	-	-	-	-
[d]	-	-	-	-	-	-
[s]	-	-	-	-	-	-
[θ]	31	10	5	5	31	6.89
[tʰ]	-	-	-	-	-	-
[z]	1	1	-	-	1	0.22
[tʃ]	-	-	-	-	-	-
[v]	39	12	10	10	39	8.67
[ð]	6	1	-	-	6	1.33
[ʃ]	-	1	-	-	-	-
Total	**450**	**180**	**180**	**180**	**450**	**100%**

NB: The results in the table are presented as a function of speaker group, with "Native English" representing native English speakers, "Native Thai" representing native Thai speakers and "L2 English" representing Thai learners of English. The red numbers signal percentage of within-category agreement between the author and NE listeners.

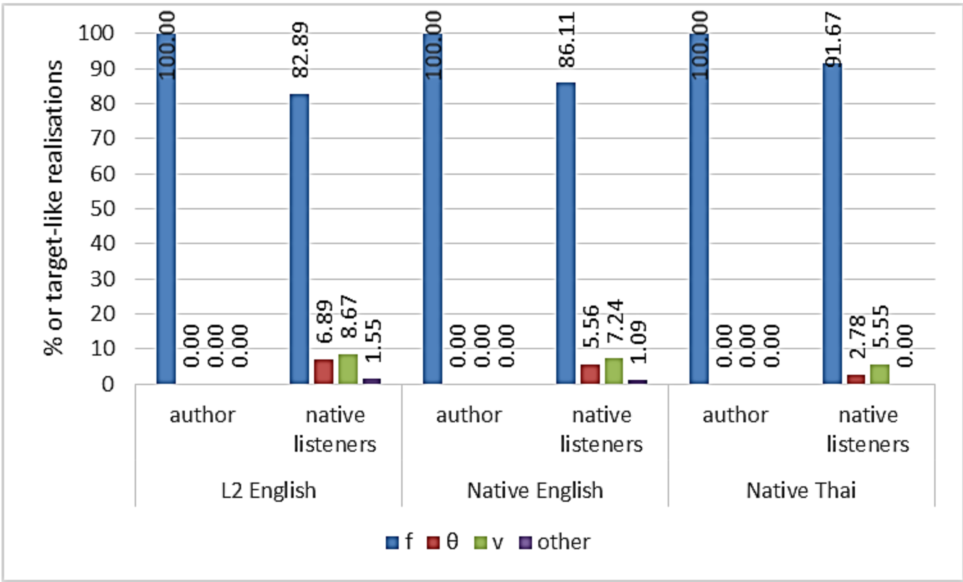

Figure 28: A comparison of /f/ realisation N = 810

Table 37. Estimates for intercept and two language groups from LMM model for sound identification task of /f/ based on d-prime results

	Estimate	Std. Error	t-value
(Intercept)	3.83355	0.19925	19.24
L2 English	-0.48904	0.20008	-2.444
Native Thai	0.06574	0.20008	0.329

L2 English /s/

The descriptive results in Table 38 presents a summary of perceptions of /s/ realisations in the three language groups based on the judgement of native English listeners compared to the impressionistic analysis in Chapter Three. It also shows that not all /s/ stimuli which were deemed to have been realised as target-like in the impressionistic analysis were accurately identified in the sound identification task; however, the percentage of correct identification for /s/ were high in the three language groups. Native English /s/ was also misidentified as [t͡ʃ, ʃ]. Native Thai /s/ was also incorrectly identified as [z]. L2 English /s/ had patterns of identification rather similar to those of native English /s/, being misidentified as [ʃ] and similar to those of native Thai /s/ in being misidentified as [z]. In addition, it was also incorrectly identified as [θ, ð]. When concentrating on the overall performance of [s] identification by native listeners and averaging the accuracy of L2 English [s] identification regardless of being target-like or non-target-like, the percentage of correct sound identification of /s/ was 82.89% which is high but lower than the percentage of target-like /s/ realisations by the author (100.00%) (see Figure 29). The results from d-prime show that listeners were more sensitive to native English stimuli (M = 4.28, SD = 0.49) and native Thai stimuli (M = 4.28, SD = 0.62) than L2 English stimuli (M = 3.76, SD = 0.33) ones. Tukey's HSD post-hoc test based on d-prime results showed a significantly higher sensitivity in the identification for the /s/ for native English stimuli than for L2 English stimuli (b = 0.52, SE = 0.21, $p < 0.05$, also see Table 39). It also showed a significantly lower sensitivity in the identification of the /s/ for L2 English stimuli than for native Thai stimuli (b = -0.51, SE = 0.21, $p < 0.05$, also see Table 39).

Table 38. A comparison of the author's transcription of /s/ tokens with native English listeners' identification of the same sounds in the sound ID task

/s/	**Author's transcription**					
Native listener perception	**L2 English [s]**		**Native English [s]**		**Native Thai [s]**	
	Nb.	**Nb.**	**Nb.**	**Nb.**	**Nb.**	**%**
[f]	-	-	-	-	-	-
[w]	-	-	-	-	-	-
[d]	-	-	-	-	-	-
[s]	**412**	**174**	**172**	**172**	**412**	**91.56**
[θ]	12	-	-	-	12	2.67
[tʰ]	-	-	-	-	-	-
[z]	24	-	8	8	24	5.33
[t͡ʃ]	-	2	-	-	-	-
[v]	-	-	-	-	-	-
[ð]	1	-	-	-	1	0.22
[ʃ]	1	4	-	-	1	0.22
Total	**450**	**180**	**180**	**180**	**450**	**100%**

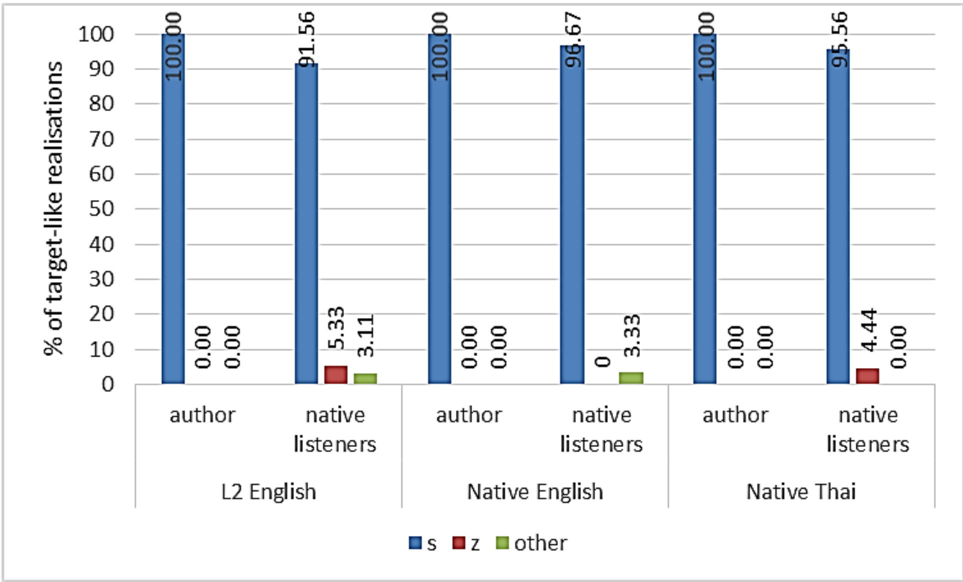

Figure 29: A comparison of /s/ realisation N = 810

Table 39. Estimates for intercept and two language groups from LMM model for sound identification task of /s/ based on d-prime results

	Estimate	**Std. Error**	**t-value**
(Intercept)	4.284928	0.156524	27.376
L2 English	-0.52058	0.214835	-2.423
native Thai	-0.009538	0.214835	-0.044

4.3.2 Sound identification of non-shared fricatives

L2 English /v/

The descriptive results for /v/ in Table 40 provides a summary of native English listeners' perceptions of /v/ in native English and in L2 English realisations that were deemed to have been realised as target-like and in L2 English realisations that were deemed to have been realised as [w] and [f]. Overall, listeners correctly identified the majority of cases of /v/ regardless of target-like or non-target-like judgements by the author. When /v/ was deemed target-like in the impressionistic analysis, it was correctly identified with extremely high percentages in both L1 and L2 English. Then when it was not deemed to be target-like, some productions were still identified with relatively high percentages (45.33% for [f] and 65.71% for [w]). The transcription of /v/ as [f] still received 31% identification accuracy and /v/ as [w] still received 17% identification accuracy. When concentrating on the overall performance of [v] identification by native listeners and averaging the accuracy of L2 English [v] identification regardless of being target-like or non-target-like, the percentage of correct sound identification of /v/ was 64.89% which is in a moderate range and higher than the percentage of target-like /v/ realisations by the author (20.00%) (see Figure 30). The results were transformed into d-prime to account for the biases in the identification task. The results from d-prime shows that listeners were more sensitive to native English stimuli (M = 4.03, SD = 0.60) than L2 English ones (M = 1.84, SD = 0.66); hence the accuracy rate was high. Tukey's HSD post-hoc test showed a significantly higher sensitivity in the identification of /v/ for native English stimuli than for L2 English stimuli (b = 2.19, SE = 0.28, p < 0.0001, also see Table 41).

Table 40. A comparison of the author's transcription of /v/ tokens with native English listeners' identification of the same sounds in the sound ID task

/v/	**Author's transcription**							
Native listener perception	**L2 English**						**Native English**	
	[v]		**[v]**		**[w]**		**[v]**	
	Nb.	**(%)**	**Nb.**	**(%)**	**Nb.**	**(%)**	**Nb.**	**(%)**
[f]	-	-	**47**	**31.33**	5	2.38	2	1.11
[w]	3	3.33	25	16.67	**37**	**17.62**	1	0.56
[d]	-	-	1	0.67	5	2.38	-	-
[s]	-	-	-	-	-	-	-	-
[θ]	-	-	6	4.00	15	7.14	-	-
[tʰ]	-	-	-	-	1	0.48	2	1.11
[z]	-	-	1	0.67	1	0.48	-	-
[t͡ʃ]	-	-	-	-	1	0.48	-	-
[v]	**86**	**95.56**	68	45.33	138	65.71	**168**	**93.33**
[ð]	1	1.11	2	1.33	7	3.33	7	3.89
[ʃ]	-	-	-	-	-	-	-	-
Total	**90**	**100%**	**150**	**100%**	**210**	**100%**	**180**	**100%**

NB: The red numbers signal percentage of within-category agreement between the author and NE listeners. For overall agreement, see Figure 30.

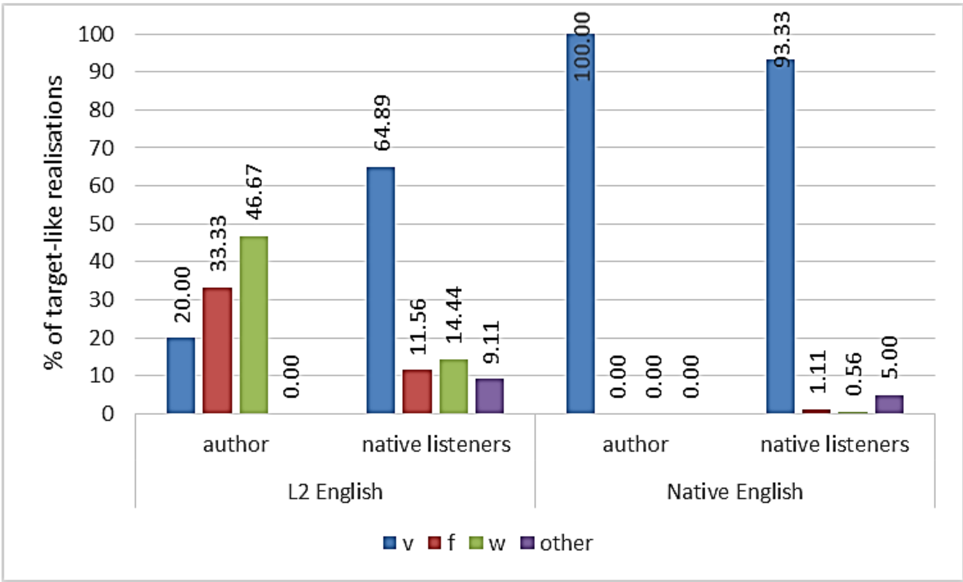

Figure 30: A comparison of /v/ realisation N = 630

Table 41. Estimates for intercept and one sound group from LMM model for impressionistic study of /v/ based on d-prime results

	Estimate	Std. Error	t-value
(Intercept)	4.0301	0.1993	20.22
L2 English	-2.1904	0.2819	-7.77

L2 English /θ/

The descriptive results for /θ/ in Table 42 provide a summary of native English listeners' perceptions of /θ/ in native English and in L2 English realisations that were deemed to have been realised either as target-like or [θ, t] and [tʰ]. Overall, listeners correctly identified the majority of cases of /θ/ when they were deemed to be realised as target-like in both L1 and L2 English. When /θ/ was not deemed target-like impressionistically, some of tokens were still correctly identified, with [t] transcriptions having a higher percentage of correct identification scores than [tʰ] (28.10% for [t] and 1.11% for [tʰ]). The majority of /θ/ tokens that were deemed to be realised as [t] were in fact misidentified as [ð], whereas the majority of /θ/ tokens that were deemed to be realised as [tʰ] were also misidentified as such. When concentrating on the overall performance of L2 English [θ] identification by native listeners and averaging the accuracy of [θ] identification regardless of being target-like or non-target-like, the percentage of correct sound identification of /θ/ was 34.24% which is low but higher than the percentage of target-like /θ/ realisations in the impressionistic analysis (33.33%) (see Figure 31). The results were transformed into d-prime to account for the biases in the identification task.

The results from d-prime shows that listeners were more sensitive to native English stimuli (M = 2.61, SD = 0.48) than L2 English ones (M = 1.32, SD = 1.08). Tukey's HSD post-hoc test showed a significantly higher sensitivity in the identification of /θ/ for native English stimuli than for L2 English stimuli (b = 1.29, SE = 0.34, p < 0.01, also see Table 43).

Table 42. A comparison of the author's transcription of /θ/ tokens with native English listeners' identification of the same sounds in the sound ID task

/θ/	**Author's transcription**							
Native listener perception	**L2 English**						**Native English**	
	[θ]		**[t]**		**[tʰ]**		**[θ]**	
	Nb.	**(%)**	**Nb.**	**(%)**	**Nb.**	**(%)**	**Nb.**	**(%)**
[f]	8	5.33	6	2.86	-	-	23	12.78
[w]	-	-	-	-	-	-	-	-
[d]	-	-	45	21.43	4	4.44	-	-
[s]	2	1.33	-	-	1	1.11	27	15.00
[θ]	**94**	**62.67**	59	28.10	1	1.11	**109**	**60.56**
[tʰ]	-	-	10	4.76	**63**	**70.00**	-	-
[z]	-	-	1	0.48	-	-	1	0.56
[tʃ]	-	-	-	-	20	22.22	-	-
[v]	13	8.67	15	7.14	-	-	6	3.33
[ð]	33	22.00	74	35.24	-	-	14	7.78
[ʃ]	-	-	-	-	1	1.11	-	-
Total	**150**	**100%**	**210**	**100%**	**90**	**100%**	**180**	**100%**

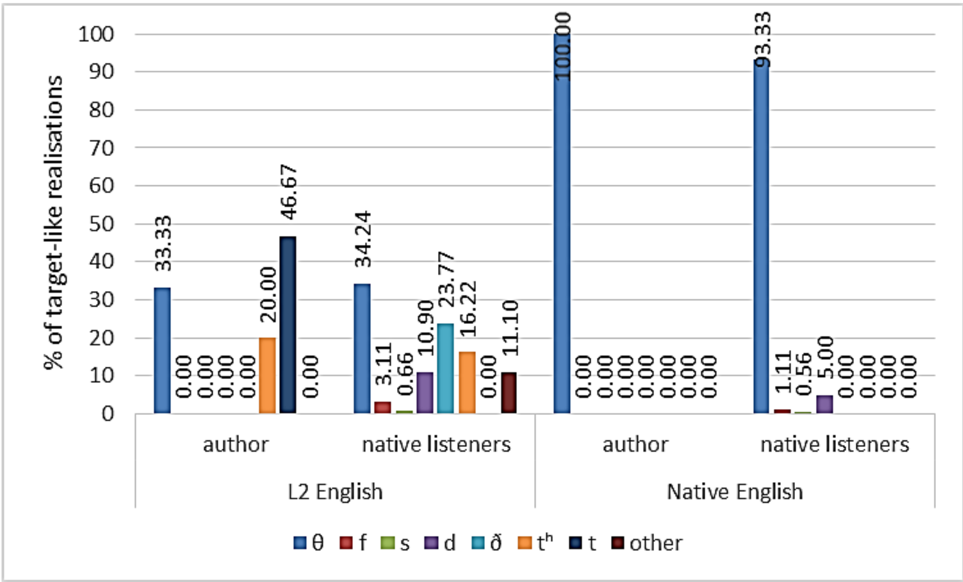

Figure 31: A comparison of /θ/ realisation N = 630

Table 43. Estimates for intercept and one sound group from LMM model for impressionistic study of /θ/ based on d-prime results

	Estimate	**Std. Error**	**t-value**
(Intercept)	2.6137	0.2636	9.916
L2 English	-1.2891	0.3389	-3.804

L2 English /ð/

The descriptive results for /ð/ in Table 44 provides a summary of native English listeners' perceptions of /ð/ in native English and in L2 English realisations that were deemed to have been realised as target-like. It also presents a summary of native English and L2 English realisations that were deemed to have been realised as [d] and [t]. Overall, listeners incorrectly identified the majority of cases of /ð/ when they were deemed to be realised as target-like in both L1 and L2 English - they were misidentified as [v]. In native English, the majority of /ð/ tokens that were deemed to be realised as [d] were identified as target-like, whereas the majority of /ð/ tokens that were deemed to be realised as [t] were misidentified as [d]. In L2 English, the majority of /ð/ tokens that were deemed to be realised as [d] were identified as [d] whereas the majority of /ð/ tokens that were deemed to be realised as [t] were misidentified as [d]. When concentrating on the overall performance of L2 English [ð] identification by native listeners and averaging the accuracy of [ð] identification regardless of whether or not it was deemed target-like, the percentage of correct sound identification of /ð/ was 12.66% which is low but higher than the percentage of target-like /ð/ realisations in the impressionistic analysis (6.67%) (see Figure 32). The results from d-prime shows that listeners were most sensitive to native English stimuli (M = 0.33, SD = 1.09) than L2 English ones (M = 0.20, SD = 1.67). However, Tukey's HSD post-hoc test based on d-prime results did not show a significant difference in sensitivities of /ð/ for native English stimuli than for L2 English stimuli (p = 0.42, also see Table 45).

Table 44. A comparison of the author's transcription of /ð/ tokens with native English listeners' identification of the same sounds in the sound ID task

/ð/	Author's transcription											
Native listener perception	L2 English						Native English					
	[ð]		[ð]		[ð]		[ð]		[ð]		[ð]	
	Nb.	Nb.	Nb.	Nb.	Nb.	Nb.	Nb.	(%)	Nb.	(%)	Nb.	(%)
[f]	-	-	-	-	-	-	-	-	5	1.52	1	1.11
[w]	-	-	-	-	-	-	-	-	2	0.61	-	-
[d]	2	3	3	3	3	3	3	6.67	**214**	**64.85**	46	51.11
[s]	-	-	-	-	-	-	-	-	-	-	-	-
[θ]	-	1	1	1	1	1	1	-	4	1.21	9	10.00
[tʰ]	-	-	-	-	-	-	-	-	26	7.88	13	14.44
[z]	-	1	1	1	1	1	1	-	-	-	-	-
[t͡ʃ]	-	-	-	-	-	-	-	-	-	-	-	-
[v]	17	74	74	74	74	74	74	56.67	49	14.85	4	4.44
[ð]	11	**41**	**41**	**41**	**41**	**41**	**41**	36.66	29	8.79	17	18.89
[ʃ]	-	-	-	-	-	-	-	-	1	0.30	-	-
Total	**30**	**120**	**120**	**120**	**120**	**120**	**120**	**100%**	**330**	**100%**	**90**	**100%**

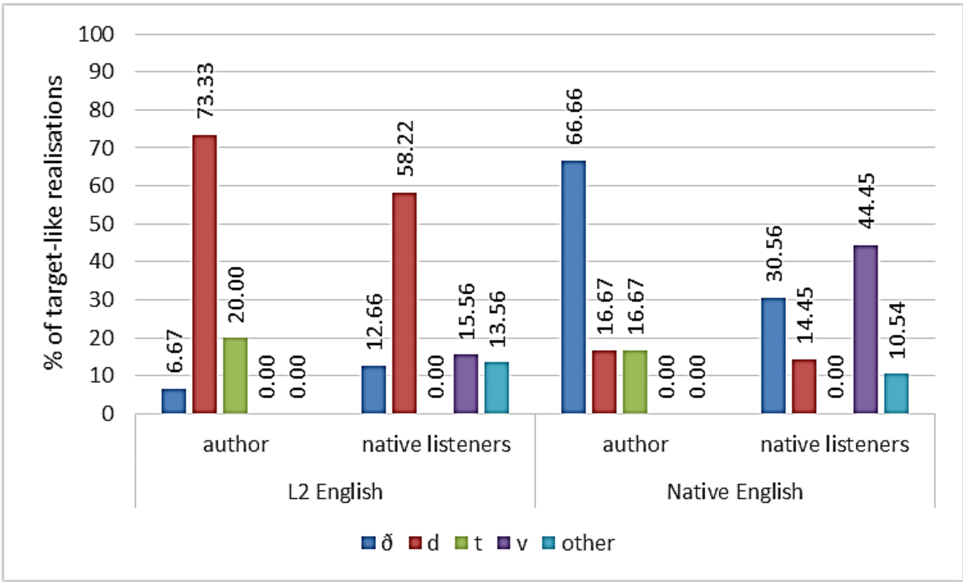

Figure 32: A comparison of /ð/ realisation N = 630

Table 45. Estimates for intercept and one sound group from LMM model for impressionistic study of /ð/ based on d-prime results

	Estimate	Std. Error	t-value
(Intercept)	0.3291	0.4463	0.738
L2 English	-0.133	0.6217	-0.214

L2 English /z/

The descriptive results for /z/ in Table 46 provide a summary of native English listeners' perceptions of /z/ in native English and in L2 English realisations that were deemed to have been realised as target-like and in L2 English realisations that were deemed to have been realised as [s]. Overall, listeners correctly identified the majority of cases of /z/ when they were deemed to be realised as target-like in both L1 and L2 English. In L2 English, the majority of /z/ tokens that were deemed to be realised as [s] were identified as [s]. When concentrating on the overall performance of L2 English [z] identification by native listeners and averaging the accuracy of [z] identification regardless of whether or not they were deemed target-like, the percentage of correct sound identification of /z/ was 37.78%, which is low but higher than the percentage of target-like /z/ realisations in the impressionistic analysis (20.00%) (see Figure 33). The results from d-prime shows that listeners were most sensitive to native English stimuli (M = 4.51, SD = 0.31) than L2 English ones (M = 3.03, SD = 0.62). Tukey's HSD post-hoc test showed a significantly higher sensitivity in the identification of /z/ for native English stimuli than for L2 English stimuli (b = 1.48, SE = 0.15, p < 0.0001, also see Table 47).

Table 46. A comparison of the author's transcription of /z/ tokens with native English listeners' identification of the same sounds in the sound ID task

/z/	**Author's transcription**					
Native listener perception	**L2 English**				**Native English**	
	[z]		**[s]**		**[z]**	
	Nb.	**(%)**	**Nb.**	**(%)**	**Nb.**	**(%)**
[f]	-	-	-	-	-	-
[w]	-	-	-	-	-	-
[d]	-	-	-	-	-	-
[s]	1	1.11	**278**	**92.67**	1	0.56
[θ]	-	-	-	-	-	-
[tʰ]	-	-	-	-	-	-
[z]	**89**	**98.89**	81	27.00	**178**	**98.89**
[tʃ]	-	-	-	-	-	-
[v]	-	-	-	-	1	0.56
[ð]	-	-	-	-	-	-
[ʃ]	-	-	1	0.33	-	-
Total	**90**	**100%**	**360**	**100%**	**180**	**100%**

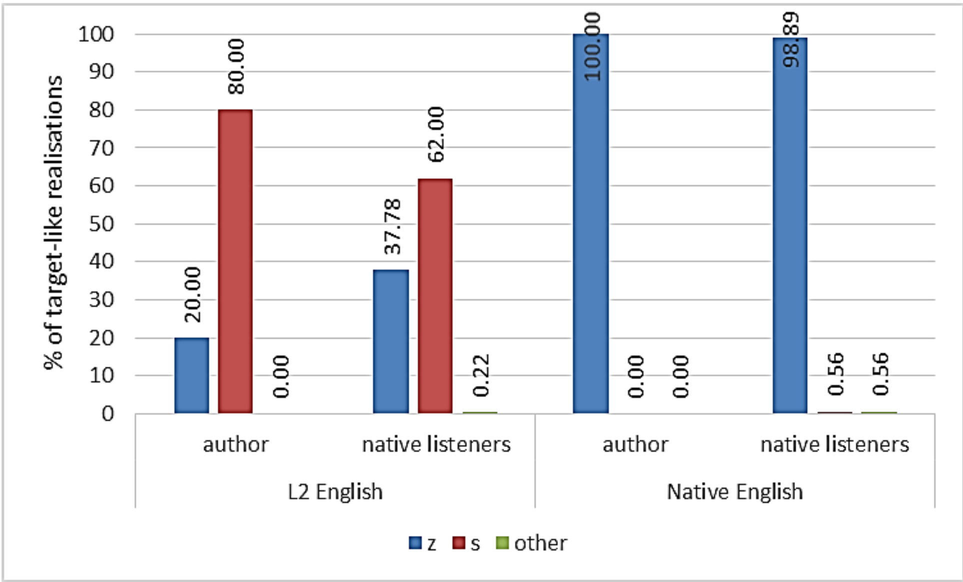

Figure 33: A comparison of /z/ realisation N = 630

Table 47. Estimates for intercept and one sound group from LMM model for impressionistic study of /z/ based on d-prime results

	Estimate	Std. Error	t-value
(Intercept)	4.5061	0.1557	28.93
L2 English	-1.4807	0.1476	-10.03

L2 English /ʃ/

The descriptive results for /ʃ/ in Table 48 provides a summary of native English listeners' perceptions of /ʃ/ in native English and in L2 English realisations that were deemed to have been realised as target-like and in L2 English realisations that were deemed to have been realised as [t͡ʃ]. Overall, listeners correctly identified the majority of cases of /ʃ/ when they were deemed to have been realised as target-like in both L1 and L2 English. In L2 English, the majority of /ʃ/ tokens that were deemed to have been realised as [t͡ʃ] were indeed misidentified as [t͡ʃ]. When concentrating on the overall performance of L2 English [ʃ] identification by native listeners and averaging the accuracy of [ʃ] identification regardless of being target-like or non-target-like, the percentage of correct sound identification of /ʃ/ was 52.22% which is low and lower than the percentage of target-like /ʃ/ realisations in the impressionistic analysis (80.00%) (see Figure 34). The results were transformed into d-prime to account for the biases in the identification task. The results from d-prime shows that listeners were more sensitive to native English stimuli (*M* = 4.15, *SD* = 0.76) than L2 English ones (*M* = 2.49, *SD* = 0.64). Tukey's HSD post-hoc test based on d-prime results showed a significantly higher sensitivity in the identification of /ʃ/ for native English stimuli than for L2 English stimuli (*b* = 1.66, *SE* = 0.23, *p* < 0.01, also see Table 49).

Table 48. A comparison of the author's transcription of /ʃ/ tokens with native English listeners' identification of the same sounds in the sound ID task

/ʃ/	**Author's transcription**					
Native listener perception	**L2 English**				**Native English**	
	[ʃ]		**[t͡ʃ]**		**[ʃ]**	
	Nb.	**(%)**	**Nb.**	**(%)**	**Nb.**	**(%)**
[f]	-	-	-	-	4	2.22
[w]	-	-	-	-	-	-
[d]	-	-	-	-	-	-
[s]	-	-	-	-	-	-
[θ]	-	-	-	-	-	-
[tʰ]	-	-	-	-	-	-
[z]	-	-	-	-	-	-
[t͡ʃ]	127	35.28	**88**	**97.78**	8	4.44
[v]	-	-	-	-	1	0.56
[ð]	-	-	-	-	-	-
[ʃ]	**233**	**64.72**	2	2.22	**167**	**92.78**
Total	**360**	**100%**	**90**	**100%**	**180**	**100%**

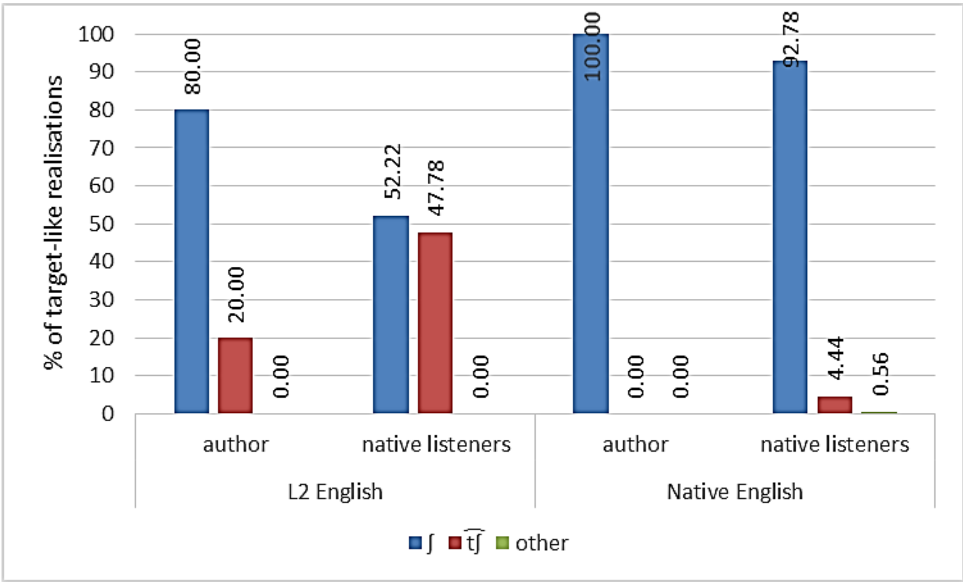

Figure 34: A comparison of /ʃ/ realisation N = 630

Table 49. Estimates for intercept and one sound group from LMM model for impressionistic study of /ʃ/ based on d-prime results

	Estimate	**Std. Error**	**t-value**
(Intercept)	4.1515	0.2224	18.664
L2 English	-1.664	0.2313	-7.194

4.4 Discussion

Before discussing the sound identification results, the overall results mirror the impressionistic results that shared sounds were easy to identify, but non-shared sounds were difficult. The reader also needs to be reminded that the results of this chapter were based on a 10% randomised list from a front high vowel context. It is possible that when a larger number of realisations is included or when the realisations are from other vowel contexts, the results might be different.

4.4.1 Sound identification of shared L2 fricatives

For /f/, the CAH-based hypothesis was that the degree of correct sound identification of L2 English /f/ will be high. This hypothesis is confirmed as it was found that L2 English /f/ had high percentages of correct identification. The result of d-prime scores showed that English listeners were more sensitive to native Thai /f/ and native English /f/ as compared to L2 English /f/, while there was no difference in sensitivity in perceiving native Thai and native English /f/. In the impressionistic analysis, the percentage of native Thai /f/ productions that were deemed target-like was 100% and the gap between native Thai /f/ and L2 English /f/ realisations that were deemed target-like was not great. In this analysis, however, the percentage of sound identification of native Thai /f/ was approximately 10% higher than that of L2 English /f/ and it might be possible that the ratio of sound identification of L2 English /f/ and native Thai /f/ in the high vowel context was higher than in the contexts of front low vowel and the back high vowel. This assumption was further investigated. In the impressionistic results, it was indeed the case that whereas the production of native Thai /f/ was 100% for all vowel contexts (front high, front low, back high), L2 English /f/ was highest in the back high vowel context (100%), followed by the front low vowel (99.11%) and front high vowel (98.89%) contexts, respectively. Hence, it is possible that the difference that is largest between the scores of correct sound identification of native Thai /f/ and L2 English /f/ causes a higher difference in percentages in this task. The percentage of correct identification of L2 English /f/ was as high as that of native English /f/ (over 80%) leading to the conclusion that L2 Thai learners found L2 English /f/ easy to produce. This result is in agreement with the study of Chunsuvimol and Ronakiat (2000) on L2 English /f/ production by Thai L2 learners, who found that in initial position, learners had no difficulty producing L2 English /f/. The results that all sound groups of /f/ were occasionally identified as [θ] might be because of similarities in their spectral characteristics (Strevens, 1960). Some of the /f/ realisations in all sound groups were also identified as [v], which might be due to the similar place and manner of articulations of these two sounds, i.e. both are classified as labio-dental fricatives. The other possibility is that these /f/ realisations that were identified as [v] were actually voiced or had a minor voicing lead as they were produced in a carrier sentence.

Regarding the production of /s/, the hypothesis based on the CAH was that the percentage of correct sound identification of /s/ in L2 English will be high. This hypothesis is confirmed as it was found that it had a high percentage of correct identification. However similar to the d-prime results of /f/, English listeners were more sensitive to native English and native Thai /s/ than L2 English /s/. The result of high percentage of correct identification for L2 English /s/ is consistent with the impressionistic analysis and prior research (Ronakiat, 2002; Kanokpermpoon, 2004), showing again that in initial position this sound does not present a problem for L2 Thai speakers. The results that some native Thai and L2 English /s/ realisations that were deemed to be realised as [s] were misidentified as [z] might be because these two sounds are similar in both place and manner of articulation, i.e. they are alveolar fricative and are voicing counterparts in English. In addition, the reason why some of native English and L2 English /s/ realisations that were deemed target-like were misidentified as [ʃ] might be because they are both voiceless sibilants. The misidentification of /s/ as [ʃ] is also shown in the work of Kraljic and Samuel (2007) as these two sounds are very similar in duration and amplitude - their main difference lies in frequency with /s/ has higher frequency than [ʃ].

4.4.2 Sound identification of non-shared L2 fricatives

For L2 English /v/ production, the CAH-based hypothesis that the degree of sound identification for L2 English will be low, and this was confirmed with low percentage of correct identification. When looking at the overall percentage of correct identification, it was found that that identification of native English /v/ was much higher than that of L2 English /v/ (93.33% as opposed to 64.89%). The d-prime result showed that English listeners were more sensitive to native English /v/ than L2 English /v/. These results are consistent with the impressionistic results. The low percentage of correct identification of L2 English /v/ is in contrast to the findings by Brière and Chiachanpong (1980) that L2 Thai learners in the US had one non-target-like production in word list elicitation and all /v/ realisations were judged as target-like in free speech, which might be due to the high level of English proficiency of the L2 Thai learners in that group; however, their finding related to only three occurrences of initial /v/ in free speech.

The results of this study partially contradict those of Chunsuvimol and Ronakiat (2000) in that in their conversation task, target-like production amounted to approximately 50% to 75%, whereas in minimal pairs – which might be more similar to the word list elicitation in this study – the mean of target-like L2 English /v/ production was more than 85%; thus the percentage found in this study is closer to the result for L2 English /v/ production in the conversation task in Chunsuvimol and Ronakiat's (2000)'s study than the word list task. This might be because in their study, the subjects were English major students who tended to have a high level of interest in English and were more likely to have received special training in English pronunciation from phonetic courses for English majors at university level. Hence when they produced words in isolation, they were more careful, yielding a higher degree of target-likeness as opposed to spontaneous speech. Unlike this study, the subjects were L2 Thai learners with various educational backgrounds.

Looking back at the percentages of substitutions for L2 English /v/ that were deemed to be realised as [f] and [w] but that were identified as correct by native speakers, this suggests that native speakers of English have a broader set of acceptable variants for /v/. The [f] realisations that were identified as correct are not surprising as it is common for the voiced fricatives to be wholly or partially devoiced in the speech of native English speakers (Docherty, 1992). Furthermore, it is likely that the native English listeners would be exposed to input from non-native speakers, which might increase their recognition of L2 English /v/ production by these speakers. Both [f] and [w] were also common substitutions for L2 English /v/ among L2 learners of English in other studies, such as Cantonese learners (Meng *et al.*, 2007), Hong Kong learners (Hung, 2000) and Thai learners (Chunsuvimol and Ronakiat, 2000; Chunsuvimol and Ronakiat, 2001).

Regarding the production of L2 English /θ/, the CAH-based prediction is that the degree of correct sound identification for L2 English will be low. The low percentage of sound identification of L2 English /θ/ supports this hypothesis. The d-prime result showed that English listeners were more sensitive to native English /θ/ than L2 English /θ/. The results were in agreement with those in the study by Flege *et al.* (1995a), who found significantly lower correct sound identification of /θ/ for Italian speakers of English with an AOA of 11 to 21 years than native speakers of English. The results here might be because the participants in this study arrived in the L2 country (the UK) when they were adults; the post-puberty period might correlate with the difficulty in producing L2 English /θ/.

In addition, the percentage of correct sound identification of native English /θ/ was not very high (approximately 60%) and approximately 10% were identified as [f] and [s]. As noted by Harris (1958), discriminating /θ/ from /f/ is best done when it is on the total duration of the vocalic element. In this study, 50 ms of the following vowel was used in the stimuli, which might have caused ambiguity in /θ/ identification. The result of misidentification of /θ/ as [f] is consistent with Johnson and Babel's (2010) and Tabain's (1998) study in which the pair /θ/-/f/ was rated as highly similar in the perception of English listeners. The misidentification of /θ/ as [s] is perhaps not surprising as these two sounds tend to be perceived as similar, especially in L2 production, as found in prior research (Weinberger, 1990; Kanokpermpoon, 2004; Wester *et al.*, 2007). It might also be possible that this /θ/ realisation that was identified as [s] was produced as sibilant. The low correct identification rate for /θ/ across native and non-native speakers suggests that the task was hard and an inclusion of a larger portion of the vowel might have improved its identification; however, it might also have presented further cues to the non-native production of the target words based on vocalic cues, which is why it was not adopted in this study as noted above. The misidentification of L2 English /θ/ production that was deemed target-like as [ð] might be because /ð/ is a voiced counterpart of /θ/ – they share both manner and place of articulation, i.e. both of them are dental fricatives. Most L2 English /θ/ realisations that were deemed to have been realised as [t] and were identified as [ð]; as for [θ], this might be due to the experience of interaction with non-native speakers. For example, in the work of Burkardt (2008), [t] was the substitution for both L2 English /ð/ and /θ/ by L2 Thai learners.

For L2 English /ð/ production, the CAH-based hypothesis predicts that the degree of correct sound identification for L2 English /ð/ will be low. This is confirmed by the low percentage of correct sound identification for L2 English /ð/. The d-prime score results showed that English listeners were equally sensitive to the stimuli of L1 and L2 English /ð/. The low percentage of correct identification of L2 English /ð/ suggests that L2 Thai learners had difficulty producing L2 English /ð/. These results are consistent with those concerning Italian speakers of English with an AOA of nine to 21 years in Flege *et al.* (1995a), showing lower correct identification of /ð/ than for native speakers of English. Taken together, these results suggest that when L2 learners arrive in the L2 country post puberty, their production of accurate L2 /ð/ tends to be lower than when arriving in puberty. If this holds true, it suggests that AOA is related to the production of L2 English /ð/.

In addition, it is interesting that in L1 and L2 English /ð/ production, most instances were identified as [v]. In Harris's (1958) study, when the friction portion of /ð/ was followed by the vocalic portion of /v/, listeners mostly identified the fricative as [v]. When the friction portion of the fricative was /v/ and the vowel portion was /ð/, listeners mostly identified the fricatives as [v]. There were a high percentage of accurate responses only when both the friction portion and vocalic portion were taken from a /ð/ token. This is similar to the reason as for /θ/ as mentioned above. The result that native English [d] tokens which were substituted for /ð/ were mostly identified as [ð] supports the notion that this substitution is common in the speech of native speakers of English (Labov, 1969); however the result that L2 English [d] substituted for /ð/ was mostly identified as [d] suggests that the substitutions of native English speakers and L2 English learners might have different sound qualities. Further investigation would be interesting.

Regarding the production of L2 English /z/, the hypothesis based on the CAH was proposed that the degree of sound identification of L2 English /z/ would be low. These were confirmed, suggesting that the L2 Thai learners had difficulty producing this sound. The d-prime results showed that English listeners were more sensitive to native English /z/ than L2 English /z/. The low percentage of correct identification of L2 English /z/ is consistent with previous studies (Brière and Chiachanpong, 1980; Charmikorn, 1988). Many instances in which L2 English [s] was substituted for /z/ were also correctly identified as [z], which might be because [s] is a common variant for /z/ among native English speakers (Stevens *et al.*, 1992).

For L2 English /ʃ/ production, the CAH-based hypothesis predicts that the degree of correct sound identification of L2 English /ʃ/ will be low. The percentage of correct identification of L2 English /ʃ/ was not high confirming CAH hypothesis. The d-prime results showed that English listeners were more sensitive to native English /ʃ/ than L2 English /ʃ/. The lower percentage of correct identification of L2 English /ʃ/ also contradicts the impressionistic results which might be due to the different linguistic backgrounds of the listeners. The perception of L2 production depends on many factors related to the listeners (Hayes-Harb and Watzinger-Tharp, 2012), including linguistic background and experience of varieties of speech (Munro *et al.*, 2006). I, as someone who is phonetically trained, took the role of listener in the impressionistic analysis. However, I have a similar linguistic background to the L2 speakers, whereas the listeners in the sound identification task were native English speakers, with varying degrees of experience in non-native speech. It is possible that native speakers of English managed to notice the difference between L1 and L2 English /ʃ/ pronunciations, esp. that L2 English /ʃ/ was made with lip-rounding or with shorter duration as they might be affricate-like. These characteristics of L2 production are influenced by their Thai /t͡ɕʰ/, which is different from native English /ʃ/ in lip rounding and duration. I, on the other hand, as a person with similar linguistic background, might not be able to notice the affrication of L2 English /ʃ/, resulting in perceiving native English /ʃ/ and L2 English /ʃ/ as similar. The difference in the linguistic backgrounds of the groups of speakers might have resulted in differences in perception. For example, Munro *et al.* (2006) carried out an intelligibility test with listeners from different L1 backgrounds: Cantonese, Japanese, Mandarin and English. The participants listened to the English utterances spoken by speakers of different languages – Cantonese, Japanese, Polish and Spanish – and wrote down the utterances in a dictation task. The results showed that Japanese listeners gave significantly higher intelligibility scores for Japanese-accented English uttered by Japanese speakers compared to English listeners, suggesting that the perception of listeners regarding L2 production depends not only on the L2 speech properties, but also the linguistic background of the listeners. This result supports that of Major *et al.* (2002), who found that L2 listeners sometimes had a higher understanding of speech in their own accent than another accent. Their study also suggested that the intelligibility of L2 speech need not be judged only by native listeners of the L2, but could also be judged by non-native listeners. Thus, the results in this study in terms of the high percentage of target-like L2 English /ʃ/ following impressionistic analysis but not in the sound identification task by native listeners might be due to the similar linguistic background of the author, who carried out the impressionistic analysis, and L2 Thai learners.

The results from the impressionistic study regarding most non-shared fricative production (L2 English /v, θ, ð, z/) showed these to be difficult for the L2 Thai learners; the sound identification results also showed low percentages for production that was deemed target-like are consistent with the non-existence of L2 sounds that might hinder L2 learning or production as predicted in CAH. However, the descriptive statistics showed that all four non-shared sounds had higher percentages of correct sound identification compared to the percentages of realisations that were deemed-target-like in the impressionistic study: /v/ (64.89% vs. 13.20%); /θ/ (34.24% vs. 30.48%); /ð/ (12.67% vs. 7.83%); /z/ (37.78% vs. 21.6%). This suggests a broader set of acceptable variants of L2 English production in native English speakers' perception, such that even though the L2 production might not fit a canonical version of what the IPA sound suggests, native speakers of L2 still recognise the intended sounds. It is possible that in actual communication, these native listeners had the opportunity to converse with speakers with different linguistic backgrounds, not only including native speakers of L2 who might be American, British, Australian and so on, but also many non-native speakers of L2 who use English to convey messages. Also in this task, native listeners were interacting with the author who was a speaker of Thai-accented English and explained them the task before they listened to the stimuli. This may have increased their exposure to more variants of the target fricatives, thus enlarging the acceptable set of variants and aiding sound recognition. These results suggest that the aim of having target-like production for L2 learners might be an unrealistic ideal and that it is not necessary in real communication (as pointed out in the interviews with the Thai L2 learners in Chapter Three) as interlocutors tend to process the hearing of the sound based on their linguistic experience, yielding a higher degree of sound identification.

4.5 Conclusion

In summary, this chapter has presented the results of a sound identification task for seven L2 English fricatives as judged by native English listeners. The results suggest that the L2 Thai learners had no difficulty producing the shared sounds, /f/ and /s/, as the percentages of correct identification of the L2 English of these sounds were high. The results of the sound identification task for shared fricatives thus support the hypotheses based on the CAH that shared sounds are easy to produce.

For non-shared fricatives, on the other hand, the results of low percentages of correct sound identification in L2 English /v, θ, ð, z, ʃ/ production suggest that the L2 learners had difficulty producing L2 non-shared fricatives. The results of L2 English /v, θ, ð, z/ are consistent with the impressionistic results. The results related to the production of L2 English /ʃ/ were surprising as they were in contrast to the impressionistic results, i.e. the percentage of correct sound identification was lower than was found in the impressionistic analysis, which might be due to the different linguistic backgrounds of the listeners in these two tasks. CAH-based hypothesis accurately predicts the results of all non-shared fricatives, as it predicts that non-shared sounds are difficult to produce.

Results from these results provide an insight into the extent to which target-likeness of L2 fricative production is possible when judged by native speakers of L2.

To explore the degree of foreign accent in L2 fricative production in the realisations that were deemed target-like, the results from an accent rating task will be presented in Chapter Five.

Chapter 5. Accent rating analysis of L2 fricatives

5.1 Introduction

While analysis in the previous two chapters focussed on the degree to which L2 Thai learners produce target-like realisations of English fricatives regardless of whether these realisations are Thai-accented, this chapter aims to assess the degree to which L2 fricative production is native-like. In this chapter, English listeners heard a subset of the same stimuli as used in the previous two chapters. This was a subset of the tokens judged to be target-like in the impressionistic analysis along with tokens produced by the native English speakers, and tokens produced by the monolingual native Thai speakers. All of these were rated for English native-likeness on a nine-point Likert scale (1 'completely accented', and 9 'native-like'). Including both Thai and English fricatives produced by native speakers of the respective languages was done in order to delve deep into the notion of similarity in sound production across languages, by both native and non-native speakers of the language. To that end, the native English listeners were not informed of whether the fricative tokens they heard were Thai or English, and within the latter, whether they were produced by native or non-native English speakers. While all chosen tokens had been identified as the intended target fricatives based on the impressionistic analysis, the main aim was to explore the degree of perceived native-likeness in L2 Thai learners' production of shared and non-shared English fricatives. As was done for the sound identification task (Chapter 4), the stimuli comprised one word selected from the front high vowel context in native English and native Thai, since the vowels of these two languages were the most similar in terms of frontness and lip spreading.

In many studies, the chosen data for an accent rating task typically include L2 sound realisations which are both target- and non-target-like, because no distinction is made between the notions of target-likeness and native-likeness as is done in this study (e.g. Munro *et al.*, 1996; Flege *et al.*, 2003). This is despite the fact that there is no straightforward relationship between intelligibility and degree of accent in L2 speech; for instance, Derwing and Munro (2009) point out that heavily accented speech might be highly intelligible but unintelligible speech cannot have a native-like accent. Taking this point into account, the author decided to investigate the degree of native-likeness only in the realisations that were deemed to have been realised as target-like in Chapter Three as only they have potential to sound native-like. The main aim was to test the SLM assumption that not only difference but similarity between L1 and L2 phones inhibits native-like acquisition of shared sounds.

For the non-shared fricatives, even though the high number of non-target-like realisations of these sounds goes against SLM assumptions about similar vs. new phones, target-like realisations were included in the task in order to still test for the degree of native-like attainment in their production.

In order to include a fairly flexible notion of realisations that were deemed target-like, minor deviations from a proto-typical realisation were also included, especially if these were also part of the realisations that were exhibited by native speaker participants. This, for instance, included the voiced/voiceless counterpart of the target fricatives. Hence, the L2 non-target-like [f] produced for L2 English /v/ and the L2 non-target-like [s] produced for L2 English /z/ were also included for the targets /v/ and /z/ respectively.

While there have been impressionistic investigations for L2 English fricative production by Thai learners (e.g. Brière and Chiachanpong, 1980; Chunsuvimol and Ronakiat, 2001), none has also included an accent rating task to investigate the degree of native-likeness in the accents of Thai speakers producing L2 English fricatives.

5.2 Methodology

5.2.1 Listeners

The listeners for these tasks were 10 female British native speakers (see Table 50), eight of whom had participated in the identification task. All of them were studying at Newcastle University at the time of this study, most of them (90%) were studying speech and language therapy and had some phonetics training and represented the different dialect regions of the UK spoken by students at the University. The ages of the listeners ranged from 19 to 34 years at the time of the experiments (*M* = 22, *SD* = 4.50). Eight of them had participated in the sound identification task. However to minimise a training effect, i.e. exposure to the same materials, these listeners were asked to participate in the two tasks on different days. None of them reported having speech or hearing disorders nor did they have prior knowledge of Thai.

Table 50. British listeners in accent rating task

Code	Age	Birthplace	Place that has lived for most of life	Programme of study
300101	23	Portsmouth	Portsmouth	Speech and Language Therapy
300102	22	Nottingham	North England	Speech and Language Therapy
300103	19	Middlesbrough	Northwest England	Speech and Language Therapy
300104	20	Nottingham	Nottingham	Speech and Language Therapy
300105	20	Hampshire	Hampshire	Speech and Language Therapy
300106	34	Church Village, Wales	Newcastle	Education
300107	19	Southampton	Southampton	Speech and Language Therapy
300108	19	Manchester	Warrington	Speech and Language Therapy
300109	21	Leicester	Leicester	Speech and Language Therapy
300110	23	Macclesfield	Macclesfield	Speech and Language Therapy

5.2.2 Stimuli

The stimulus selection process here was similar to that in the sound identification task: 10% of occurrences of each type were computed to arrive at the number of stimuli for each target fricative. The number of males and females producing fricatives was balanced.[16] However, the set differs from that for the identification task in that all sounds were those which had target-like realisations based on the results in Chapter Three. An exception was made for /v/ and /z/ which also had non-target-like realisations; these two sounds had such a high number of non-target-like realisations which were voiceless counterparts possible in regional varieties, i.e. [f] as a substitution for /v/ and [s] as a substitution for /z/ (Docherty, 1992). Other substitutions, for /v/ and /z/ such as [w] for /v/, were not included as they were not possible regional variants; hence, there was high potential for these to be judged as heavily accented. To prevent an effect of lexical bias as mentioned in the stimuli preparation description in the sound identification analysis, only a portion of the word was played to the listeners. The total number of stimuli for all target fricatives was 190. All listeners practised their rating judgments by listening to 10 practice items and rating them on a 9-point scale before moving on to the actual stimuli, which were each played three times in three blocks, randomised. This resulted in 580 stimuli for this experiment ([190

[16] The reason why the stimuli in this chapter were also divided according to gender unlike those in the previous chapter because in accent rating, native-likeness is more specific to gender; hence the stimuli needed to be controlled. The sound identification task aimed to test whether realisations of fricative were target-like or not.

stimuli × 3 times] + 10 stimuli for the training phase). The sound extraction was similar to that in the stimuli preparation in the sound identification task. Table 51 presents the number of stimuli for each target fricative.

Table 51. Number selection of each target sound balanced for gender

Target sound	Language	Realisation	Gender of speaker	Number of stimuli
/f/, /s/	Native Thai	The realisations of these five target sounds were impressionistically transcribed as target-like.	Male	3
			Female	3
	Native English		Male	3
			Female	3
	L2 English		Male	8
			Female	8
/θ/, /ʃ/	Native English		Male	3
			Female	3
	L2 English		Male	8
			Female	8
/ð/	Native English		Male	3
			Female	3
	L2 English		Male	5
			Female	7
/v/	Native English	[v]	Male	3
			Female	3
	L2 English		Male	8
			Female	8
		[f]	Male	4
			Female	8
/z/	Native English	[z]	Male	3
			Female	3
	L2 English		Male	8
			Female	8
		[s]	Male	8
			Female	8

5.2.3 Data collection

In this experiment, nine-point likert scale ratings were used, anchored at 1 (non-native-like) to 9 (native-like) (Derwing and Munro, 1997; Ingvalson *et al.*, 2011). Rather than using the more limited scale seen in previous work, e.g. three in Flege *et al.* (2003), five in Munro *et al.* (1996), this extended scale was employed to lessen a ceiling effect, the level above which variance in the independent variable cannot be measured (Southwood and Flege, 1999; Polat and Schallert, 2013). The listeners were given the following statement: *At the beginning of each of the following slides, the first part of an English word will be played. Please rate how native-like you think this production is on a scale from 1 to 9.* They knew that the stimuli they were hearing were produced by native and non-native speakers, but they did not know which stimuli were from which language group. Similarly to the sound identification task, they could press the ‘replay’ button if they wished to hear the sound again and could change their answer if they wanted. When they were confident with their answers, they pressed the ‘next’ button. They were given a break after every 100 stimuli. The approximate time taken in this experiment was one hour and the listeners were given £5 as a ‘thank you’ gift. Figure 35 shows an example of the screen for the accent rating task.

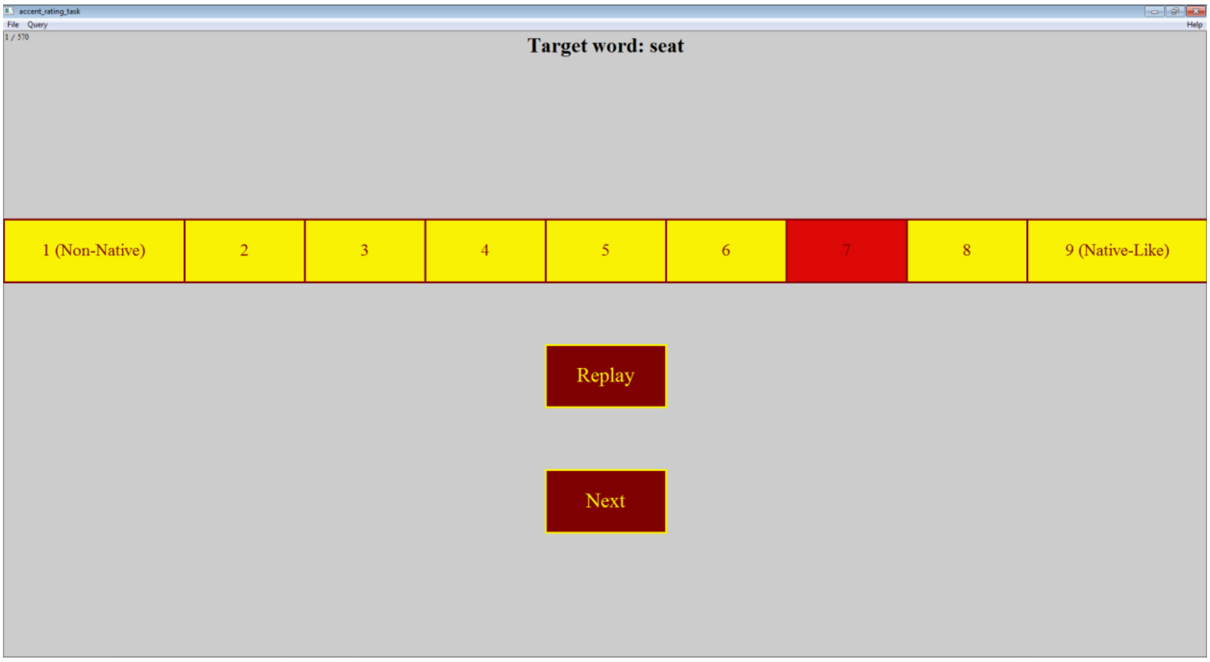

Figure 35. Example of screen in the accent rating task

5.2.4 Data analysis

For the accent rating test, descriptive data were analysed using SPSS and were reported in mean, median, SD, variance and number of cases for each target fricative. Then the data were transformed into d-prime following Macmillan and Creelman (2005) which take into account the cumulative ranking of the data. The interpretation of d-prime was that the higher the value, the more sensitive the listeners are to the sounds. LMMs were used with the d-prime score (interval) as the dependent variable. The independent variable was the language group (factor). The listener (factor) was fit as random intercept with stimuli (interval) as random slope. The language groups were structured as follows:

1. Three groups (native Thai, native English and L2 English) for /f, s/ production.

2. Two groups (native English and L2 English) for /θ, ð, ʃ/.

3. Three groups (native English, target-like L2 English and non-target-like L2 English) for /v, z/.

An example of R code for the LMMs is as follows:

```
model1 <- lmer (dprime ~ language + (1+stimuli |listener), data =
        data1.frame, REML = TRUE)
```

Tukey's HSD post-hoc tests were run using the *lsmeans* package in R statistical software (Lenth, 2014) based on the LMM to see the results of significances and means for all language pairs, coded as the following example:

```
lsmeans(model1, pairwise~language, adjust="tukey")
```

Then the p-values reported from pairwise comparison are one-tailed.

5.3 Results for the accent rating task

The main result from this task is that the median scores of fricatives of all language groups were low (between 2.98 - 5.79). The possible causes for the low scores will be discussed in the discussion part.

5.3.1 Shared fricatives

L2 English [f]

Table 52 shows descriptive data of [f] ratings for all three languages including mean, median, SD, variance and number of cases. Median values of native-likeness scores of [f] for L2 English was higher than native English and native Thai [f] (Figure 36); note, however, that d-prime scores of native-likeness for [f] that were highest in native English followed by native Thai and L2 English, respectively (Figure 37). This may be due to the variance around the median that seems to be largest for the L2 English group compared to native English and native Thai. Tukey's HSD post-hoc test on d-prime results showed that native English listeners were more sensitive to native English [f] than L2 English [f] (b = 0.76, SE = 0.17, p < 0.0001). However they were less sensitive to L2 English [f] than native Thai [f] (b = -0.41, SE = 0.17, p < 0.05). The native English has a tendency to be higher than native Thai [f] (p = 0.05). Although the median seems to show relatively identical scores, d-prime results show a different pattern, as they provide an insight into how sensitive the English listeners are to the different stimuli; they seem to be more sensitive to native English stimuli, followed by native Thai and L2 English. Table 53 presents estimates for two sound groups from LMM for accent rating task of [f].

Table 52: Mean, median, SD, variance and number of cases of raw scores of accent rating for [f]

	L2 English	Native English	Native Thai
Mean	4.98	4.21	4.56
Median	5.00	4.00	4.00
SD	2.34	2.40	2.50
Variance	5.45	5.75	6.27
Number of cases	480	180	180

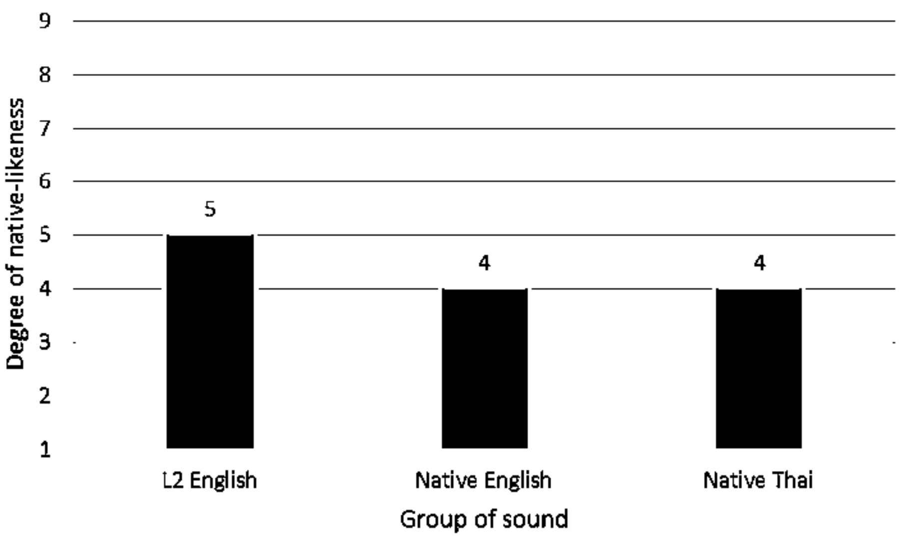

Figure 36. Median native-likeness scores for [f] according to group of sound produced from raw scores

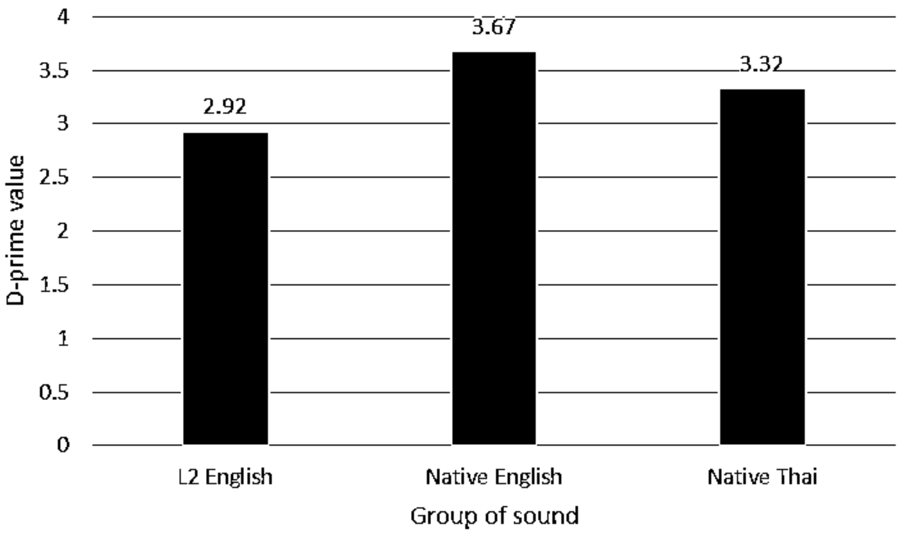

Figure 37. Mean d-prime scores for [f] according to group of sound

Table 53. Estimates for two language groups from LMM for accent rating task of [f]

	Estimate	**Std. Error**	**t-value**
(Intercept)	3.6718	0.4288	8.563
L2 English	-0.7552	0.1712	-4.411
Native Thai	-0.347	0.1712	-2.027

L2 English [s]

Table 54 shows descriptive data of [s] for all language sounds including mean, median, SD, variance and number of cases. Figure 38 shows that the median values of native-likeness scores of [s] for native English were higher than L2 English and native Thai whereas Figure 39 shows d-prime scores of native-likeness for [s] that were highest in native Thai followed by L2 English and native English, respectively. Tukey's HSD post-hoc test on d-prime results showed that native English listeners were less sensitive to native English [s] than native Thai /s/ (b = -0.69, SE = 0.14, p < 0.0001). They had a tendency to be less sensitive to L2 English [f] than native Thai [f] (b = -0.40, SE = 0.14, p < 0.01). They had a tendency to be less sensitive to native English [s] than L2 English [s] (p = 0.06). Although the median seems to show relatively identical scores, the d-prime results show that listeners seem to be more sensitive to native Thai stimuli, followed by L2 English and native English. Table 55 presents estimates for two sound groups from LMM for accent rating task of [s].

Table 54: Mean, median, SD, variance and number of cases of raw scores of accent rating for [s]

	L2 English	Native English	Native Thai
Mean	5.30	5.65	4.73
Median	5.00	6.00	5.00
SD	2.39	2.28	2.55
Variance	5.69	5.18	6.48
Number of cases	480	180	180

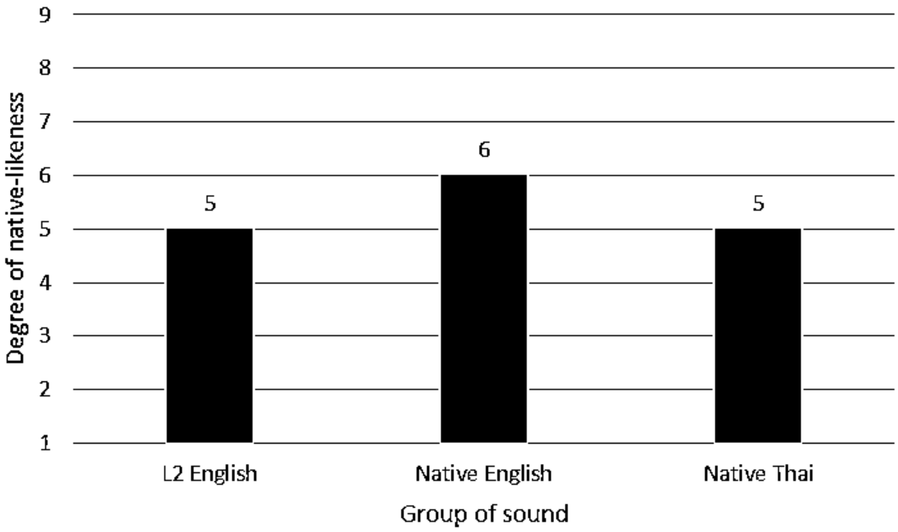

Figure 38. Median native-likeness scores for [s] according to group of sound produced from raw scores

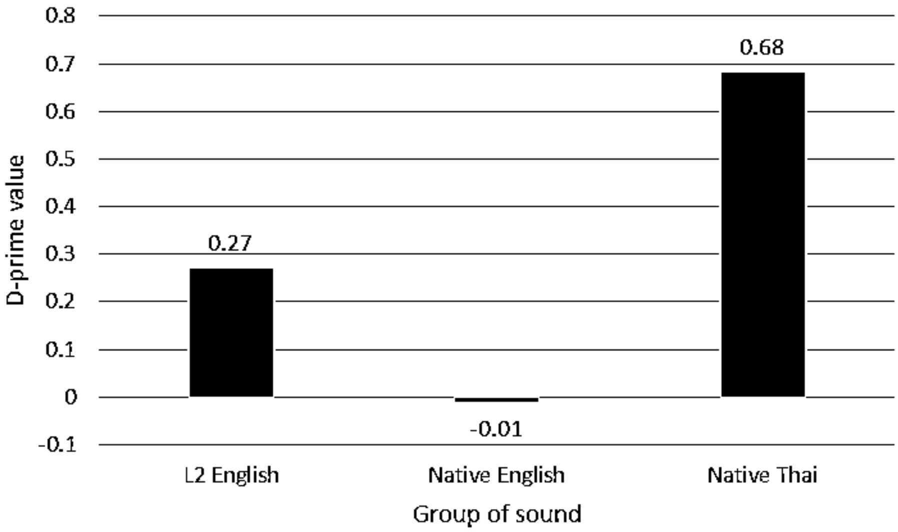

Figure 39. Mean d-prime scores for [s] according to group of sound

Table 55. Estimates for two language groups from LMM for accent rating task of [s]

	Estimate	**Std. Error**	**t-value**
(Intercept)	1.6832	0.3413	4.932
L2 English	0.2833	0.1428	1.983
Native Thai	0.688	0.1428	4.816

5.3.2 Non-shared fricatives

L2 English /v/

Table 56 shows descriptive data of /v/ for all language sounds including mean, median, SD, variance and number of cases. Figure 40 shows the median values of native-likeness scores for [v] that were high for native English and L2 English [v] which were in turn higher than L2 English [f] whereas Figure 41 shows d-prime scores of native-likeness for [f] that were highest in L2 English [f] followed by L2 English [v] and native English, respectively. Tukey's HSD post-hoc test on d-prime results showed that native English listeners were less sensitive to native English than L2 English [f] (b = -1.22, SE = 0.18, p < 0.0001), but they were more sensitive to L2 English [f] than L2 English [v] (b = 1.17, SE = 0.18, p < 0.0001). It also showed that these listeners were equally sensitive to native English [v] and L2 English [v] (p = 0.48). The median seems to show that the score of L2 English [f] is lower than native English [v] and L2 English [v]. Consistently, the d-prime results show the same pattern in that they seem to be more sensitive to L2 English [f] stimuli than L2 English [v] and native English [v]. Table 57 presents estimates for two sound groups from LMM for accent rating task of /v/.

Table 56: Mean, median, SD, variance and number of cases of raw scores of accent rating for /v/

	L2 English (non-target-like)	**L2 English (target-like)**	**Native English**
Mean	3.68	5.08	5.11
Median	3.00	5.00	5.00
SD	2.50	2.51	2.42
Variance	6.26	6.28	5.83
Number of cases	480	360	180

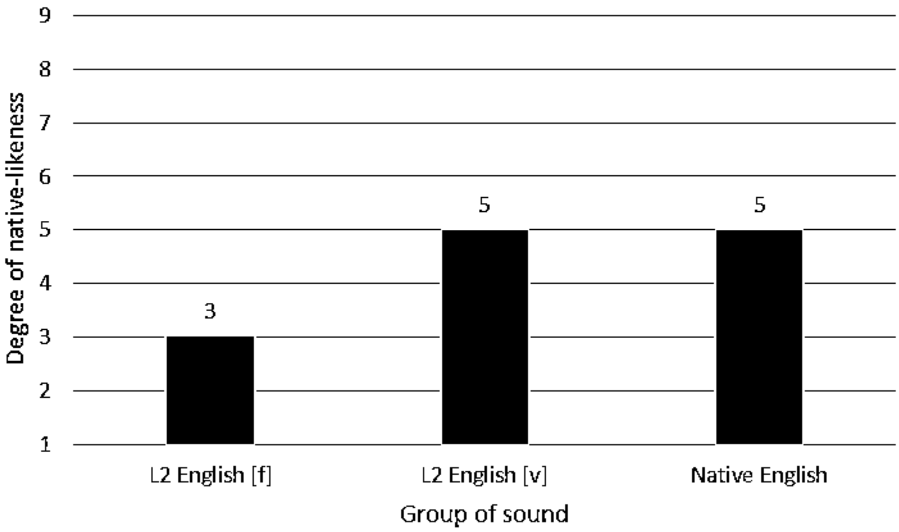

Figure 40. Median native-likeness scores for /v/ according to group of sound produced from raw scores

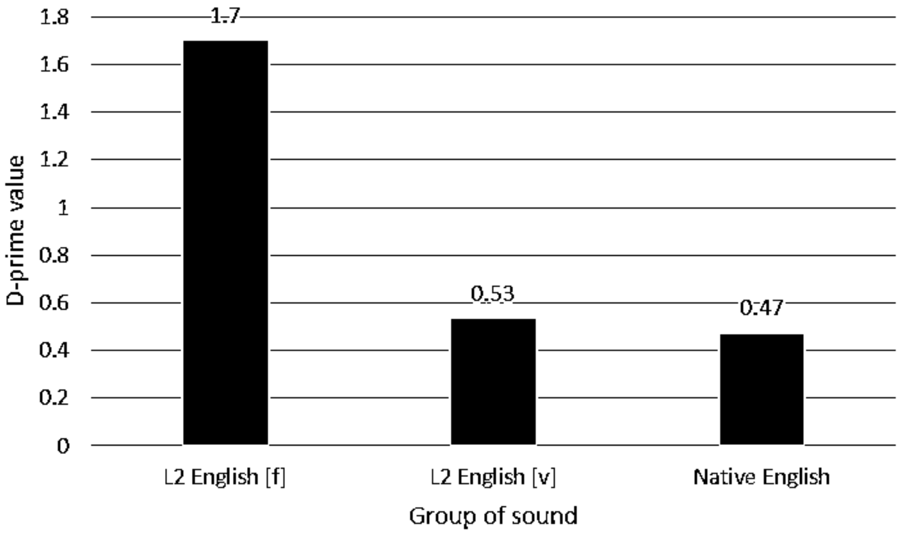

Figure 41. Mean d-prime scores for /v/ according to group of sound

Table 57. Estimates for two language groups from LMM for accent rating task of /v/

	Estimate	**Std. Error**	**t-value**
(Intercept)	3.8708	0.3474	11.141
L2 English [f]	1.2202	0.1792	6.807
L2 English [v]	0.0521	0.1792	0.291

L2 English [θ]

Table 58 shows descriptive data of [θ] for all language sounds including mean, median, SD, variance and number of cases. Figure 42 shows the median values of native-likeness scores for [θ] that were equal for native English and L2 English whereas Figure 43 shows d-prime score of native-likeness for [θ] of L2 English that were higher than that of native English. Tukey's HSD post-hoc test on d-prime results showed that native English listeners were equally sensitive to native English and L2 English [θ] (p = 0.29). Although the median seems to show identical scores, the d-prime results show a different pattern as they are showing that listeners were more sensitive to L2 English [θ] than native English [θ]. Table 59 presents estimates for one sound group from LMM for accent rating task of [θ].

Table 58: Mean, median, SD, variance and number of cases of raw scores of accent rating for [θ]

	L2 English	**Native English**
Mean	5.28	5.56
Median	6.00	6.00
SD	2.54	2.66
Variance	6.44	7.09
Number of cases	480	180

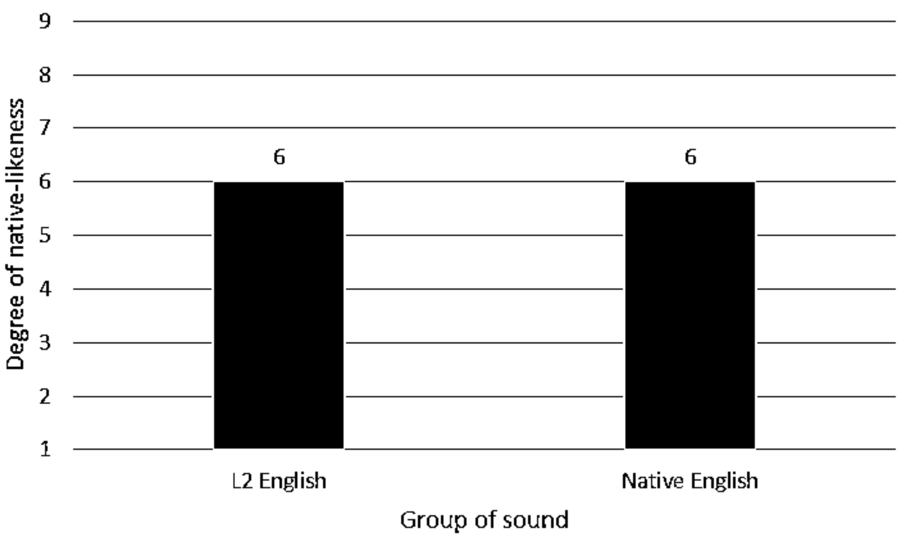

Figure 42. Median native-likeness scores for [θ] according to group of sound produced from raw scores

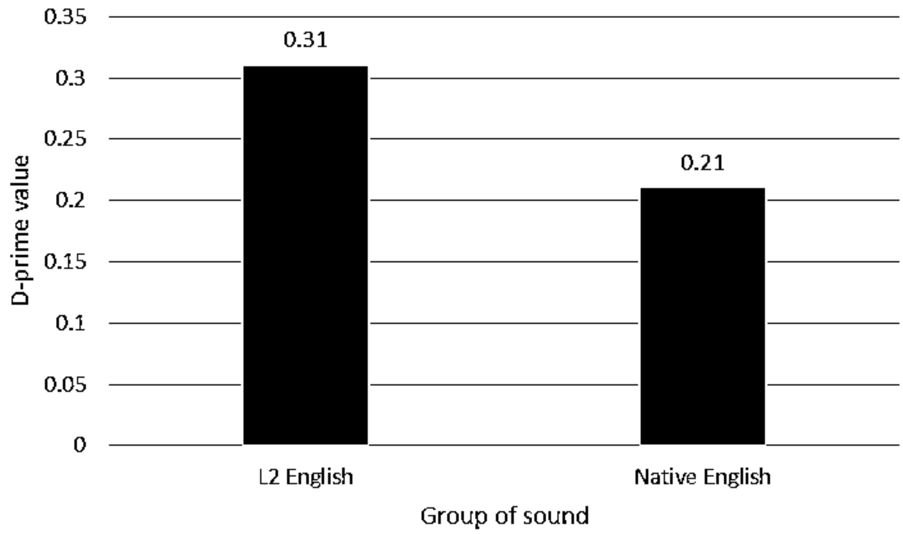

Figure 43. Mean d-prime scores for [θ] according to group of sound

Table 59. Estimates for one language groups from LMM for accent rating task of [θ]

		Estimate	Std. Error	t-value
(Intercept)		2.7175	0.4052	6.707
L2 English		0.103	0.1816	0.567

L2 English [ð]

Table 60 shows descriptive data of [ð] for all language sounds including mean, median, SD, variance and number of cases. Figure 44 shows the median values of native-likeness scores for [ð] that were higher for native English than L2 English whereas Figure 45 shows d-prime score of native-likeness for [ð] of L2 English that were higher than that of native English. Tukey's HSD post-hoc test on d-prime results showed that native English listeners were less sensitive to native English [ð] than L2 English [ð] (b = -0.59, SE = 0.20, $p < 0.01$). Although the median seems to show relatively identical scores, d-prime results show a different pattern as they are showing that listeners were more sensitive to L2 English [ð] than native English [ð]. Table 61 presents estimates for one sound group from LMM for accent rating task of [ð].

Table 60: Mean, median, SD, variance and number of cases of raw scores of accent rating for [ð]

	L2 English	Native English
Mean	5.18	5.74
Median	5.00	6.00
SD	2.49	2.47
Variance	6.20	6.09
Number of cases	360	180

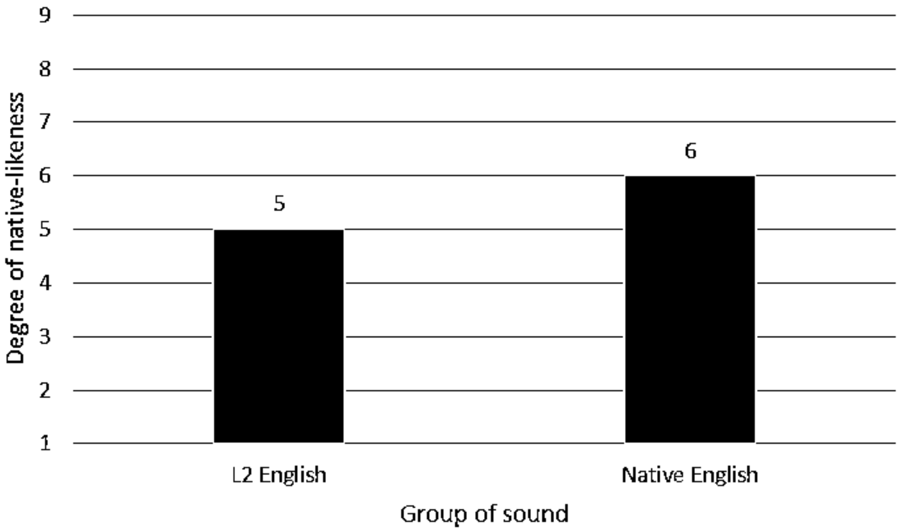

Figure 44. Median native-likeness scores for [ð] according to group of sound produced from raw scores

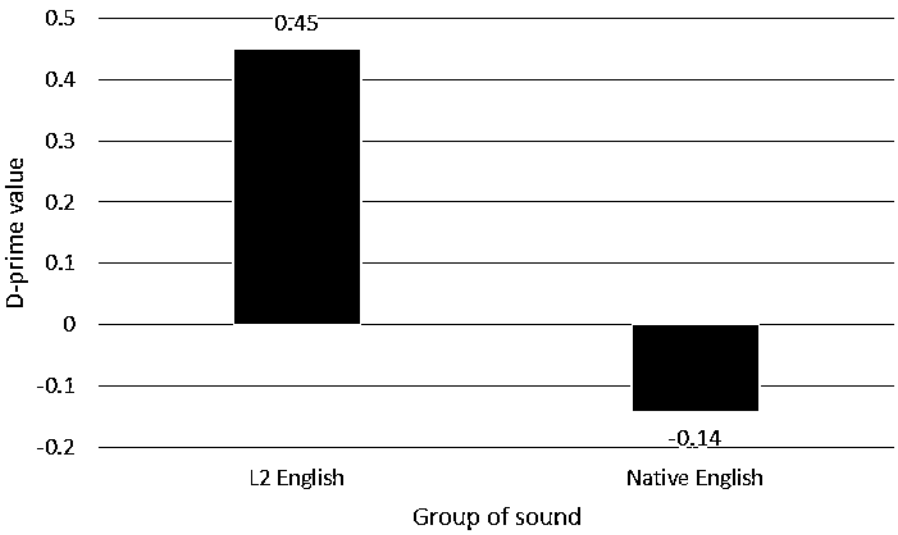

Figure 45. Mean d-prime scores for [ð] according to group of sound

Table 61. Estimates for one language groups from LMM for accent rating task of [ð]

		Estimate	Std. Error	t-value
(Intercept)		2.3489	0.4439	5.291
L2 English		0.5891	0.2005	2.939

L2 English /z/

Table 62 shows descriptive data of /z/ for all language sounds including mean, median, SD, variance and number of cases. Figure 46 shows the median values of native-likeness scores for /z/ that were highest for native English [z] followed by L2 English [z] and L2 English [s], respectively whereas Figure 47 shows d-prime scores of native-likeness for /z/ that were highest in L2 English [s] followed by L2 English [z] and native English [z], respectively. Tukey's HSD post-hoc test on d-prime results showed that native English listeners were less sensitive to native English [z] than L2 English [s] (b = -1.53, SE = 0.19, p < 0.0001) and L2 English [z] (b = -0.45, SE = 0.19, p < 0.05). However they were more sensitive to L2 English [s] than L2 English [z] (b = 1.08, SE = 0.19, p < 0.0001). Table 63 presents estimates for two sound groups from LMM for accent rating task of /z/.

Table 62: Mean, median, SD, variance and number of cases of raw scores of accent rating for /z/

	L2 English (non-target-like)	**L2 English (target-like)**	**Native English**
Mean	3.22	4.63	5.03
Median	2.00	4.00	5.00
SD	2.41	2.48	2.48
Variance	5.83	6.14	6.16
Number of cases	480	480	180

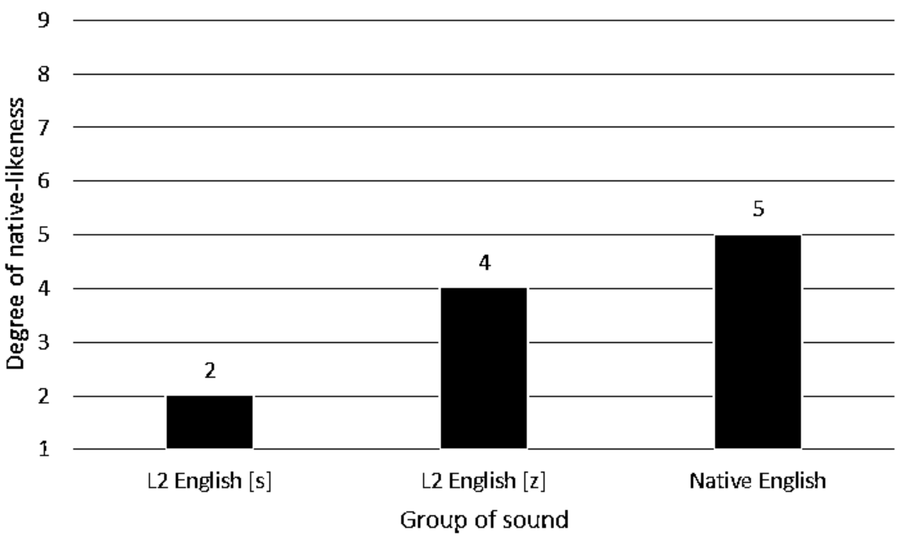

Figure 46. Median native-likeness scores for /z/ according to group of sound produced from raw scores

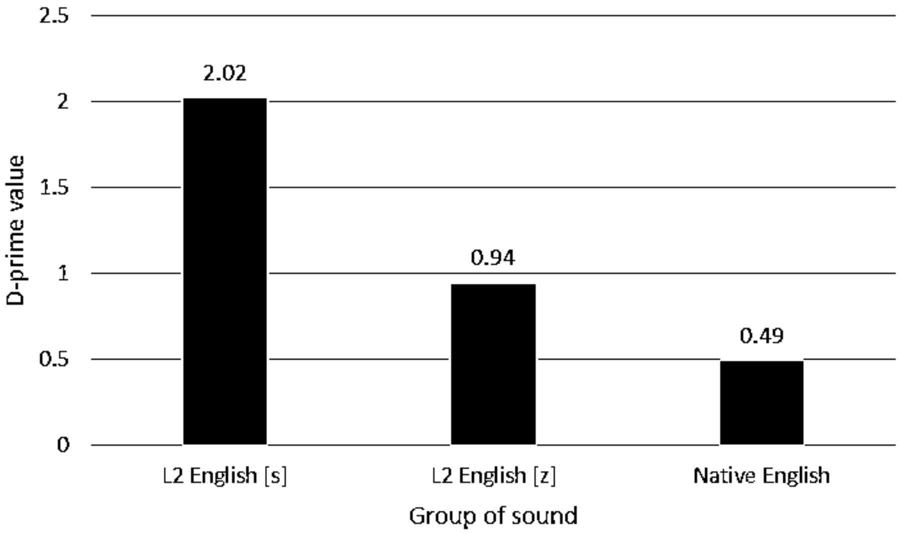

Figure 47. Mean d-prime scores for /z/ according to group of sound

Table 63. Estimates for one language groups from LMM for accent rating task of /z/

	Estimate	**Std. Error**	**t-value**
(Intercept)	3.2125	0.3847	8.352
L2 English [s]	1.5308	0.1873	8.174
L2 English [z]	0.4502	0.1873	2.404

L2 English [ʃ]

Table 64 shows descriptive data of [ʃ] for all language sounds including mean, median, SD, variance and number of cases. Figure 48 shows the median values of native-likeness scores for [ʃ] that were higher for native English than L2 English whereas Figure 49 shows d-prime score of native-likeness for [ʃ] of L2 English that was higher than that of native English. Tukey's HSD post-hoc test on d-prime results showed that that native English listeners were less sensitive to native English [ʃ] than L2 English [ʃ] (b = -1.57, SE = 0.18, p < 0.0001). The results of median and d-prime scores are thus consistent. Table 65 presents estimates for two sound groups from LMM for accent rating task of [ʃ].

Table 64: Mean, median, SD, variance and number of cases of raw scores of accent rating for [ʃ]

	L2 English	**Native English**
Mean	4.20	5.72
Median	4.00	6.00
SD	2.63	2.50
Variance	6.89	6.27
Number of cases	480	180

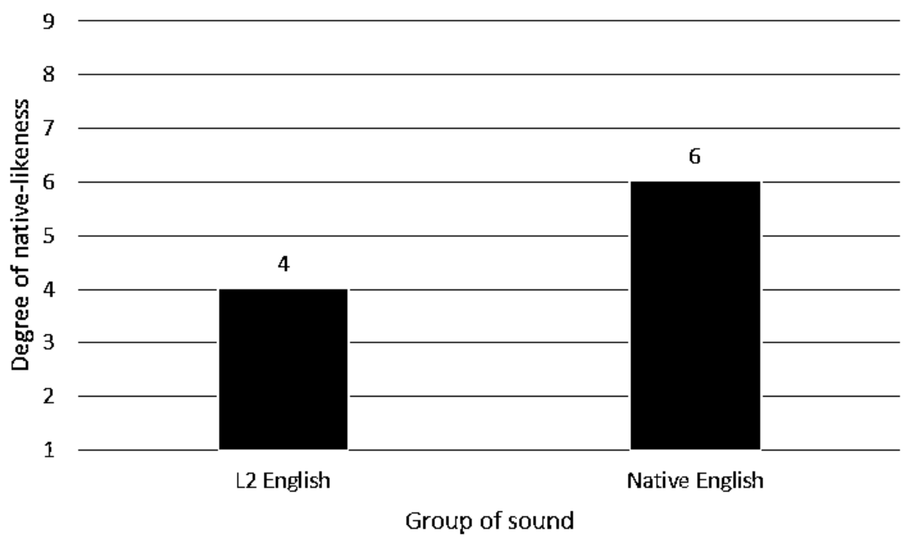

Figure 48. Median native-likeness scores for [ʃ] according to group of sound produced from raw scores

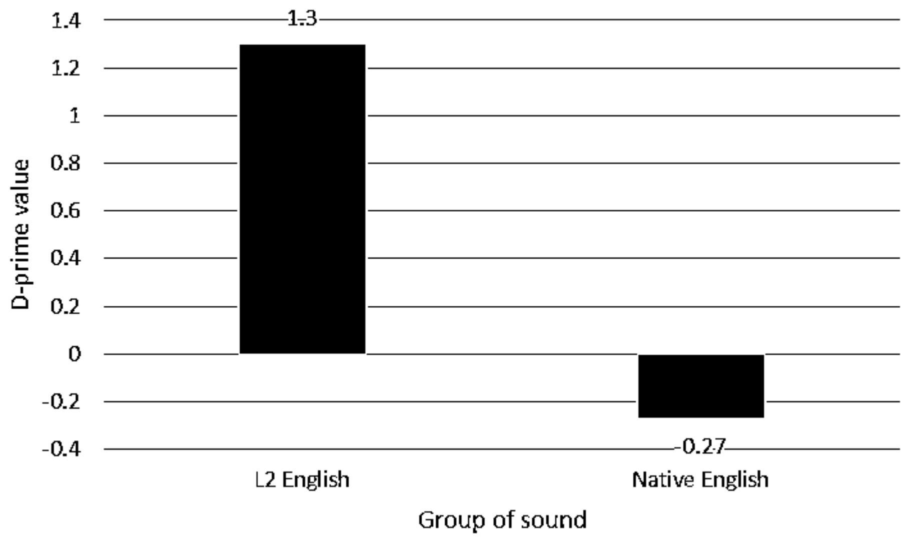

Figure 49. Mean d-prime scores for [ʃ] according to group of sound

Table 65. Estimates for one language groups from LMM for accent rating task of [ʃ]

	Estimate	**Std. Error**	**t-value**
(Intercept)	1.6241	0.518	3.135
L2 English	1.5675	0.1794	8.739

5.4 Discussion of accent rating tasks

The overall results are that the realisations impressionistically deemed to be target-like of shared [f, s] and non-shared [v, θ] were also judged to be native-like. Those realisations of non-shared [ð, z, ʃ] on the other hand were judged to be accented. One of the main points from the results of this task is the overall similarity of median raw rating scores for target-like tokens, suggesting listeners' minimal differences in their native-like perception of fricative realisations which across all three language groups. Three main reasons might explain why the listeners' rating scores of native English, native Thai and L2 English are relatively low (or hover around the middle of the scale) and are close to one another. First, a fricative is a difficult sound to perceive and has many variants in native English. Second, the exclusion of the majority of non-target-like realisations, while well justified, might have left a narrow range of realisations for listeners to rate, with no clear instances of realisations that are native-like along with realisations that are totally different. This in itself is interesting, though, as it suggests that performance on tasks like this is enhanced if there is wide variation in the quality of the stimuli, and performance is probably hindered when there is not one. Third, in this task, listeners only listened to a fricative followed by a part of the vowel rather than the whole word. Given that in normal conversation one listens whole words, we might find that distinguishing native tokens from non-native ones is better because whole word include whole vowels which might phonetically differ across native and non-native groups. However, even though the accent rating range did not show a large difference in the perception of these sound groups, it suggests that when L2 learners manage to hit a target, it is not always easy to distinguish their production from that of native speakers; rather, it is the range of non-target realisations that contribute to this perception.

5.4.1 Shared L2 fricatives

In terms of the results for L2 English [f] production, the SLM-based hypothesis predicts that the listeners' scores for native-likeness for L2 English [f] would be lower than that for native English [f]. The median scores showed that L2 English [f] received higher scores than native English and native Thai [f] and the LMM result showed that listeners were more sensitive to native English [f] and native Thai [f] than L2 English [f]. These two results thus disconfirm the hypothesis. These might suggest that it is therefore possible for the L2 production of L2 English [f] to attract ratings comparable to the productions of native speakers.

In terms of L2 English [s] production, the median accent rating scores showed that native English [s] was judged to be produced with higher degree of native-likeness than native Thai and L2 English [s]. The d-prime LMM result showed that listeners were more sensitive to native Thai [s] than L2 English and native English [s], suggesting that L2 English [s] and native English [s] were not perceived as different from one another. These results disconfirm the SLM hypothesis around performance on shared, similar, sounds, as the assumption is that L2 English [s] would receive lower scores than native English [s]. This result also suggests that the production of L2 English [s] is not always the result of transfer from native Thai [s]. This result would seem to be in contrast with the common belief that Thai learners have no difficulty in producing L2 English [s] due to positive transfer from L1 (Ronakiat, 2002; Kanokpermpoon, 2004). Rather, this result suggests that target-like native Thai [s] is different from native English [s] but that the L2 learners were successful in learning the L2 phone, supporting the notion of L2 attainment (Flege, 1995; Best and Tyler, 2007). That is shared, but similar and not identical sounds can be acquired. Furthermore, this result highlights the fact that impressionistic study is merely one aspect of investigation of L2 production and may be insufficient grounds for asserting that L2 production results from the negative or positive influence of the L1; there are other perspectives that need to be taken into consideration. For instance, L2 English [s], was rated as less accented than the native Thai [s] even though there were no differences in the target-likeness judgement of this sound in any language pairs (native English, native Thai and L2 English) based on the impressionistic analysis and the sound identification task. Equally, native Thai [f] received similar if not higher ratings on its native-likeness in English than native English [f], demonstrating that when listeners are blind to the language of the stimuli and the local phonetic cues of the L1 and L2 sounds are very similar, they are susceptible to accepting the Thai variant as an instance of an native English phoneme.

5.4.2 Non-shared L2 fricatives

Median accent rating scores for L2 English [ð, z] and [ʃ] productions that were deemed target-like were higher suggested that they were more accented than their native English counterparts. Moreover, LMM results showed that these differences were significant. L2 English [ð, z] realisations that were deemed target-like in the impressionistic analysis received low scores on both the impressionistic and sound identification tasks. In the accent rating task, their realisations that were deemed target-like also sounded accented for native listeners of British English. The results from these three tasks suggest that L2 English [ð, z] were difficult for the L2 Thai learners.

As for L2 English [ʃ], although this sound was mostly identified as target-like in the impressionistic analysis, it had low scores of target-likeness in the sound identification and low scores of native-likeness in the accent rating analysis. This demonstrates the role of listeners in identification for target-likeness and evaluation of native-like realisation. While the Thai background of the author may have led her to accept more affricated tokens as target-like realisations of English [ʃ] in impressionistic analysis due to the similarity this sound shares with Thai /t͡ɕʰ/, native listeners were less prone to do so and therefore misidentified this sound in the identification task as well as gave it lower native-like ratings. Moreover, native speakers of English might have heard lip spreading and/or shorter duration in L2 English [ʃ] than native English [ʃ], which are qualities from native Thai /t͡ɕʰ/.

Lastly, the LMM results for [v, θ] showed that the d-prime scores of their target-like realisations were no different from those of the native English counterparts, suggesting that the L2 Thai learners were successful in producing these two sounds in a native-like manner, at least the target-like renditions. Note, however, that non-target-like productions constituted a large percentage of the L2 learners' productions. The results showing that the native English speakers considered realisations of L2 English [f] for /v/ and [s] for /z/ accented are interesting as it suggests that these voiceless realisations are different from typically devoiced realisations by native English speakers.

5.5 Conclusion

This chapter explored the degree of accentedness of L2 fricative production by Thai learners and has thus considered another aspect of L2 speech production. For shared fricatives, target-like L2 English [f] seemed to attract higher scores than native Thai and native English [f] but all the scores were in a relatively narrow middle range. The results regarding target-like L2 English [s] casts doubt on the notion of positive transfer from native Thai as listeners had different sensitivity towards these two sounds. Results also showed that L2 Thai learners were successful in learning this sound, as listeners had no different degree of sensitivity for target-like native English [s] and target-like L2 English [s]. The results of both shared fricatives disconfirm the SLM-based hypothesis which suggests that shared sounds are difficult to produce accurately.

For non-shared fricatives, target-like L2 English [ð, z, ʃ] received lower scores than their native English counterparts, suggesting that even target-like realisations of L2 English [ð, z, ʃ] can still sound accented for native speakers of English. These results also suggest lower attainment of target-like L2 English [ð, z, ʃ]. However, the scores for target-like L2 English [v, θ] were no different from those of their native English counterparts, suggesting the attainment of the target-like realisations of these three sounds in L2 production.

Results from this study demonstrate that the SLM predictions around performance on shared and non-shared sounds cannot be generalised to the current context, and in fact may always need to be evaluated depending on the sound in question, the context (second or foreign language learning), and the type of analysis used. The results from this study are that shared sounds are relatively easy to produce and can be indistinguishable in their accent ratings from those of native speakers, whereas non-shared sounds are difficult. However, this does not mean that the learning of non-shared sounds is not possible. As shown in the results of [v, θ], the L2 production of these sounds in a native-like manner is feasible, suggesting that they are learnable.

In Chapter Six, I will explore the subtle phonetic details of fricative production in Thai and English using acoustic analysis in order to shed more light on the language-specific realisations of this category of sound and the degree to which L2 learners tune into that in their production.

Chapter 6. Acoustic analysis of L2 fricatives

6.1 Introduction

This chapter aims to explore the phonetic properties of L2 English sounds and compare these with L1 sounds as produced by native speakers (native English and native Thai if applicable, for shared sounds). In the accent rating task, results showed that realisations of [f, s, v, θ] that were deemed to be target-like were also rated as native-like. In this chapter we test these results further by examining the acoustic properties of realisations of these shared and non-shared sounds acoustically comparing them with those of the native speakers of each language. The aim is to evaluate whether impressionistic accounts of target- and native-likeness tally with acoustic properties that are similar to the L1 counterpart, or whether there is no straightforward relationship between the two. In doing so, we also offer baseline descriptions for the acoustic realisations of the Thai fricatives, which have so far been patchy. To this end, again, only the realisations that were deemed to have been realised as target-like based on the impressionistic analysis were acoustically investigated alongside their native L1 and L2 counterparts.

The hypotheses for this task are similar to those articulated in the accent rating task, as they both aim to analyse native-likeness of realisations that were deemed target-like. For shared fricatives, based on SLM assumptions, phonetic properties of L2 English realisations are predicted to be different from those of native English ones. This assumption is not yet confirmed due to large percentage of realisations that were deemed to have been realised as target-like in the impressionistic analysis, and those from the accent rating task which were deemed to be comparable to native-speaker productions. For non-shared 'new' fricatives, SLM-based hypothesis assumes that phonetic properties of L2 English realisations will become to be comparable to those of native English ones. This assumption has been disconfirmed due to low percentages of realisations of non-shared fricatives that were deemed target-like in both impressionistic analysis and sound identification.

To compare L2 fricative production to sounds existing in native and L2 (shared fricatives), each fricative produced in a target-like manner as deemed by the impressionistic analysis for the three groups of speakers: the L1 fricative produced by native speakers of English (native English fricative), the L1 fricative produced by native speakers of Thai (native Thai fricative) and the L2 fricative produced by L2 Thai learners of English (L2 English fricative). For non-shared fricatives, as in the accent rating task, only two groups of speakers were compared: the L1 fricative produced by native speakers of English (native English fricative) and the L2 fricative produced by L2 Thai learners of English (L2 English fricative). The productions of L1 fricatives by native speakers of English (and Thai for shared fricatives) were used as reference points. Seven acoustic measurements – peak location, centroid, SD, skewness, kurtosis, normalised amplitude and onset F2 frequency – were applied to sound tokens to determine the phonetic properties of L2 fricative production.

6.2 Methodology

6.2.1 Stimuli

The stimuli in this chapter comprised a subset of those included in the impressionistic analysis. For shared fricatives, only tokens of comparable L1 and L2 vowel contexts were included due to the influence of vowels on the acoustic patterns of the preceding fricatives. The list of English stimuli can be found in Table 66 whereas the list of Thai stimuli can be found in Table 67. For reasons of space, the front high vowel will henceforward be called ‘high vowel’, the front low vowel will be called ‘low vowel’, and the back mid to low vowel will be called ‘back vowel’. Similarly, for the Thai vowels, the front high vowel will be called ‘high vowel’, the front low vowel will be called ‘low vowel’ and the back high vowel will be called ‘back vowel’. The Thai stimuli are the same as those listed in Chapter Three and are therefore not shown here.

Table 66. English word list in the acoustic study

	Initial		
	Front high vowel (high vowel)	**Front low vowel (low vowel)**	**Back mid to low vowel (back vowel)**
/f/	feel /fiːl/	fat /fæt/	fought /fɔːt/
	fever /ˈfiːvə/	fan /fæn/	fall /fɔːl/
		fang /fæŋ/	fool /fuːl/
/v/	veal /viːl/	vat /væt/	vault /vɔːlt/
	visa /ˈviːzə/	van /væn/	volume /ˈvɒljuːm/
	veep /vip/	vampire /ˈvæmpaɪə/	vomit /ˈvɒmɪt/
			vase /vɑːz/
/θ/	thing /θɪŋ/	thank /θæŋk/	thought /θɔːt/
	thick /θɪk/		Thorne /θoːn/
	thief /θiːf/		thorax /ˈθɔːræks/
/ð/	these /ðiːz/	that /ðæt/	
	this /ðɪs/	than /ðæn/	
/s/	see /siː/	sad /sæd/	sought /sɔːt/
	seat /siːt/	sat /sæt/	soup /suːp/
		sap /sæp/	Sue /suː/
/z/	zeal /ziːl/	zap /zæp/	zoro /ˈzɒːrɒː/
	zinc /zɪŋk/		zombie /ˈzɒmbɪ/
	zee /zi/		Zara /ˈsɑːrɑː/
/ʃ/	sheet /ʃiːt/	shack /ʃæk/	shone /ʃɒn/
	ship /ʃɪp/	shat /ʃæt/	shot /ʃɒt/
	she /ʃiː/	Shammy /ˈʃæmɪ/	shop /ʃɒp/

NB: For each box in the table, the first one is the word; the second one in slashes is the IPA transcription.

Table 67: Thai word list in the acoustic study

	Initial		
	Front high vowel	**Front low vowel**	**Back high vowel**
/f/	/fîːp/ 'become flat'	/fǎːn/ 'slice'	/fûːt/ 'swell'
	/fîːk/ 'conceal'	/fâːt/ 'thrash'	/fûːk/ 'mattress'
	/fîː/ 'sound of snoring'	/fâːk/ 'side'	/fuː/ 'rise'
/s/	/sǐːn/ 'precept'	/sàːt/ 'mat'	/sǔː/ 'you'
	/sîːk/ 'piece'	/sàːk/ 'coarse'	/sùːp/ 'suck'
	/sǐː/ 'color'	/sàːp/ 'musty smell'	/sùːt/ 'snuff'

6.2.2 Acoustic analyses

The acoustic measurements were implemented using Praat 5.3.63 (Boersma and Weenink, 2012). The segmentations of fricatives and vowels were undertaken considering both the waveform and spectrogram. The onsets of fricatives and vowels were defined as the starting point of an increase in the frication noise amplitude in the waveform. The offset of the fricative was segmented at the offset of the frication noise and the first zero crossing of an increase in the glottal cycle in the following vowel. The offset of the vowel was segmented at the onset of the following vowel in the carrier phrase. Figure 50 shows an example of the fricative and vowel segmentation.

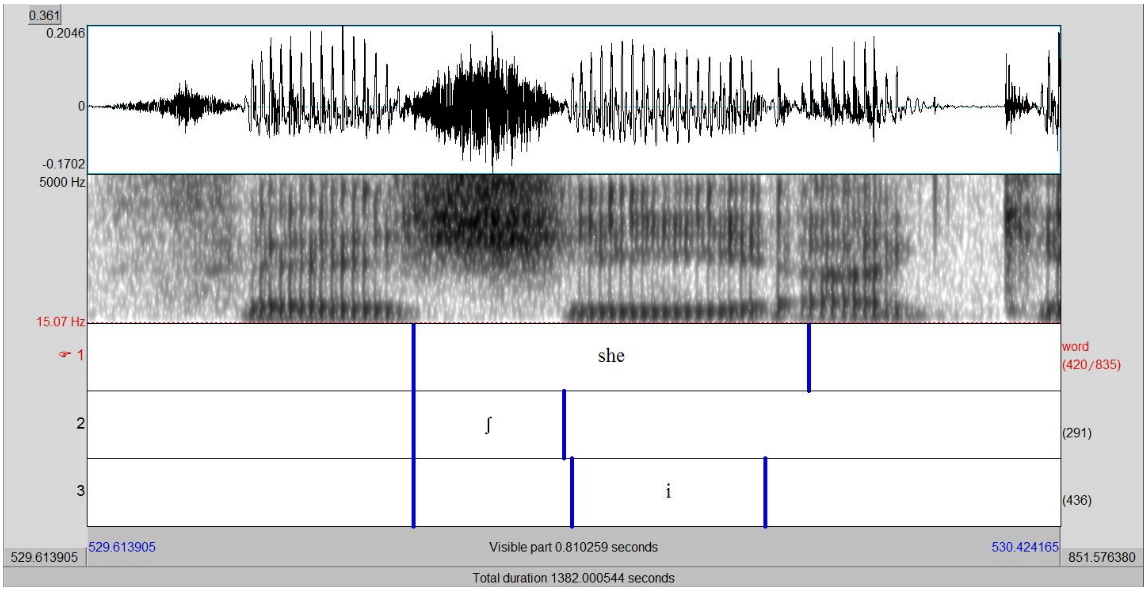

Figure 50. Segmentation of fricative and vowel in Praat

All measurements were done using Praat scripts which were partially adapted from a script written by Al-Tamimi (Al-Tamimi and Khattab, 2015). The phonetic properties of fricatives were measured using seven characteristics: four spectral moments and peak location, normalised amplitude and onset F2 frequency. The details of each acoustic measurement are as follows.[17]

Peak location and spectral moments were calculated using time-averaged spectra for fricative sounds because the native speakers and learners did not produce identical realisations of the fricatives, and these were relatively long in their production, hence this was the ideal situation for time-averaging. The multitaper estimation can also be computed but it was not implemented within Praat. After downsampling and high-pass filtering the sound file with frequency range of 0 to 16 kHz, the sound file was pre-emphasised by a factor of 0.98.[18] The fricative portion excluded the onset and offset by using 80% of the total duration of the fricative to remove coarticulatory effects of surrounding vowels.

[17] The acoustic measurements in this study were different from the ones in Roengpitya's (2011) study; it is not clear how each measurement was done in her study.
[18] The sound frequency of original sound files was 44 kHz and they were downsampled to 32 kHz. Then in the acoustic analysis, the frequency above 16 kHz was removed because it was not of interest to the present study.

Nine 10-ms Kaiser-2 windows (overlapping or not) were used. Then, a 256-point DFT spectrum was generated for each window. Time averaging was then done on the complex valued spectrum prior to log transforming the results in dB. In each frequency bin, the real and imaginary parts were averaged separately, summed and squared and then an averaged power spectrum was obtained for each fricative portion. While spectral moments were obtained based on default Praat settings, the spectral peak was obtained from the range of 0 to 16 kHz. The averaged spectrum was transformed into a logarithmic power spectral density (the LTAS function in Praat) with a 100 Hz bin size.

Normalised amplitude was obtained as the RMS amplitude in dB (the intensity function in Praat) from the whole portion of the fricative and from the vowel portion following the targeted fricative and comprised the difference between the maximum amplitude of the fricative and vowel portions (the amplitude of consonant minus the amplitude of vowel). Onset F2 frequency was obtained at the onset of the following vowel. To ensure the script extracted the correct values for onset F2 frequency, these values were checked manually. The units of the results were based on a Hertz scale and the interpolation method was linear. The outputs of the Praat scripts were in .txt and were later transferred into an Excel file for further analysis.

As fricative production is complex, research efforts were expanded on searching for acoustic correlates, for place of articulation, effort and sibilance, for different purposes, but no single acoustic measurement was found to be definite in terms of interpretation. With this shortcoming in mind, the interpretations of each acoustic measurement were taken to be as follows:

Peak location: high for sibilant (Tabain, 1998), higher effort (Maniwa *et al.*, 2009), and/or more fronted (Jongman *et al.*, 2000) fricatives.

Centroid: high for sibilant (following peak location), high for higher effort (Maniwa *et al.*, 2009) and more fronted (Jongman *et al.*, 2000) fricatives.

SD: high for non-sibilant (Jongman *et al.*, 2000; Nissen and Fox, 2005), more forwarded production as between dental and alveolar (Stoel-Gammon *et al.*, 1994) and higher effort (Maniwa *et al.*, 2009) fricatives.

Skewness: high for higher effort (Maniwa *et al.*, 2009) and more retracted (Jongman *et al.*, 2000; Nissen and Fox, 2005) fricatives.

Kurtosis: high for higher effort (Maniwa *et al.*, 2009), more retracted as between dental and alveolar (Stoel-Gammon *et al.*, 1994) and sibilant (Jongman *et al.*, 2000) fricatives.

Normalised amplitude: high for higher effort and sibilant (Stoel-Gammon *et al.*, 1994) fricatives.

Onset F2 frequency: high for higher effort (Maniwa *et al.*, 2009) and more retracted (Jongman *et al.*, 2000) fricatives.

According to Shadle (2012), higher amplitudes and frequencies can be caused by more contact, narrower constriction, more pressure and higher effort; hence the higher centroid and peak location might indicate the production with more contact, pressure, and higher effort too. The narrower constriction might result from slower conversational speaking rate that is commonly found in L2 speech production (Smiljanic and Bradlow, 2009).

Sibilants and dental fricatives tend to have larger area of production than labiodental fricatives; hence the number of variants is higher. For labiodental fricatives, as the area of articulating is smaller, they are less likely to have variants. It is appropriate for sibilants and dental fricatives to be interpreted in terms of frontness, but not for labiodental fricatives. For labiodental fricatives, the prior interpretation will be on the level of effort which is correlated to more contact and reduction of constriction area size. In addition, as it is possible that L2 Thai learners might produce L2 English [ʃ] with lip spreading based on the closet native Thai /t͡ɕʰ/, resulting in higher frequency (Shadle, 2012). Hence, the interpretation of peak location, spectral moments and onset F2 frequency for [ʃ] will also be correlated with lip spreading.

6.2.3 Statistical analysis

To investigate the acoustic characteristics of L2 fricatives and compare these with those of native English fricatives and native Thai fricatives (where applicable), linear mixed models were conducted using the *lme4* package in R statistical software (Bates *et al.*, 2014). The independent variables were language group (native English, native Thai, L2 English), gender (male, female) and vowel context (high vowel, low vowel and back vowel); the dependent variables were the acoustic measurements. In this experiment, gender and vowel context were also included as independent variables because previous studies on the acoustic characteristics of fricatives (e.g. Jongman *et al.*, 2000; Maniwa *et al.*, 2009) have shown the influence of these two factors on target fricatives. Outliers were rechecked to see if they were outliers. If they were wrong values, they would be corrected. They were removed from the data set by running boxplots in SPSS if they deviated from the mean according to the boxplots from 0.66 - 28.82%. They were removed until there were no outliers left in the boxplot chart. All models were fitted with item as random intercept as there were multiple items per category. Speaker and vowel context were fitted as random intercept and slope as speakers had produced repetitions of observations and it was likely that the production of speakers was also affected by vowel context.

The optimal model was chosen by first comparing the full model with three-way interaction, such as the lmer1 model in the examples below, to the model with two-way interaction, such as lmer2 in the examples below, using *lmer* function. Then, the *anova* function was used to assess whether the models differed or not, using the Akaike Information criterion (AIC); this was used for overall model comparisons according to the ‘smaller is better’ principle (Zheng *et al.*, 2013). If there was a significant difference between these two models, the model with the smaller AIC value was chosen; however, if there was no significant difference between these two models, the model with two-way interaction would be compared with the model using main effects only and the *anova* function was again used to select the optimal model. The R code can be exemplified as follows:

```
lmer1 <- lmer(peak ~ (1|item) + (1+vowel|speaker) +
        gender*vowel*language, data=data.frame, REML=FALSE,
        na.action=na.omit)

lmer2 <- lmer(peak ~ (1|item) + (1+vowel|speaker) + gender +
        vowel + Language + language:vowel + Language:gender +
        vowel:gender, data=data.frame, REML=FALSE,
        na.action=na.omit)

anova(lmer1,lmer2)

lmer3 <- lmer(peak ~ (1|item) + (1+vowel|speaker) + gender +
        vowel + language, data=data.frame, REML=FALSE,
        na.action=na.omit)
```

```
anova(lmer2,lmer3)
```

As the main focus here is on significant differences between language pairs, Tukey's HSD post-hoc tests were performed on factors relating to language group using the *lsmeans* package in R statistical software (Lenth, 2014); this post-hoc test is the most suitable option when sample sizes are not equal. The multiple pairwise comparisons were done only on the optimal model. The following are some examples of R code for Tukey's HSD post-hoc test:

```
lsmeans(lmer1, pairwise ~ gender*vowel*language, adjust="tukey")

lsmeans(lmer2, pairwise ~ language*vowel, adjust="tukey")

lsmeans(lmer3, pairwise ~ language, adjust="tukey")
```

The post-hoc tests were run on the optimal model after comparing the three models. All p-values based on pairwise comparison reported here are one-tailed.

In addition, the effect size of each significant contrast was calculated using Cohen's *d*, which divides effect size into three ranges: small (≤ 0.20), moderate (0.21–0.79) or high (≥ 0.80) (Cohen, 1988). The means were from the output of *lsmeans*. The SDs were gained by multiplying standard error (from *lsmeans* output) with square root of number of subjects in each language group. The effect size facilitates the interpretation of significant results by providing an estimation of the size of the effect. The results of significant difference were reported when the phonetic properties were different only in relation to language groups, but were similar in all other respects – gender and vowel context – because only differences in language groups were the focus of this analysis.

6.3 Results

6.3.1 Phonetic properties of shared fricatives

L2 English [f]

The phonetic properties of L2 English [f] were compared to native Thai [f] and native English [f]. The results are divided into seven main parts according to the acoustic measurement: peak location, centroid, SD, skewness and kurtosis, normalised amplitude and onset F2 frequency.

- Peak location (in Hz) for [f]

Table 68 shows the means and SEs of peak location (in Hz) of [f] in all contexts based on the numbers of stimuli in each language group - 462 for native English, 533 for native Thai and 1178 for L2 English. Tukey's HSD post-hoc test indicates that the peak location of native Thai [f] is significantly lower than the peak location of L2 English [f] with a small effect size (*b* = -307.58, *SE* = 116.98, *df* = 96.47, *t* = -2.629, *p* < 0.05, *d* = 0.07), suggesting that L2 English [f] is produced with more effort than native Thai [f] (see also Figure 51). The peak location of native English [f] was also found to be significantly lower than that of L2 English with a small effect size (*b* = -587.69, *SE* = 257.37, *df* = 76.19, *t* = -2.283, *p* < 0.05, *d* = 0.13), suggesting that L2 English [f] is produced with more effort than native English [f] (see also Figure 51).

Table 68. Means and SEs of language, language × gender, language × vowel, language × gender × vowel for the peak location of [f] from pairwise comparison based on LMM

		L2 English		Native English		Native Thai	
		Mean	SE	Mean	SE	Mean	SE
Language	Overall	11865.39	135.60	11277.70	216.10	11557.81	164.03
Language × Gender	Male	11537.71	184.18	10950.02	244.98	11230.13	205.34
	Female	121993.08	172.16	11605.39	245.29	11885.50	196.04
Language × Vowel context	High vowel	11967.56	150.04	11379.87	225.58	11659.98	174.38
	Low vowel	11931.56	153.74	11343.87	227.68	11623.98	180.16
	Back vowel	11697.06	148.82	11109.37	224.75	11389.48	176.03
Language × Vowel context × Gender	Male-high	11639.88	195.01	11052.19	253.35	11332.29	213.66
	Male-low	11603.88	197.91	11016.19	255.25	11296.30	218.44
	Male-back	11369.38	194.17	10781.69	252.68	11061.79	215.09
	Female-high	12295.24	183.80	11707.55	253.72	11987.66	204.82
	Female-low	12259.24	186.78	11671.55	255.55	11951.66	209.72
	Female-back	12024.744	182.71	11437.05	252.91	11717.16	206.14

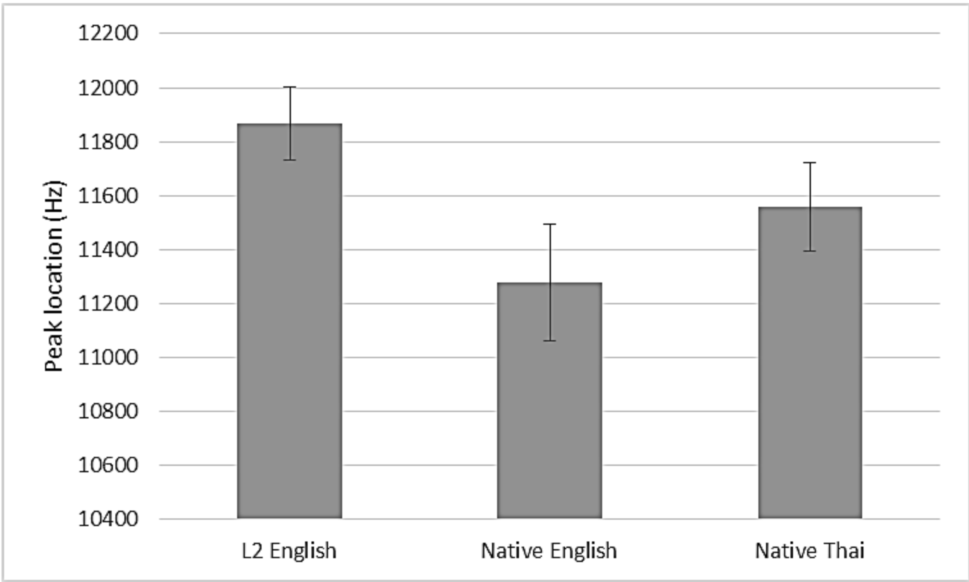

Figure 51. Means of peak location (Hz) for [f] according to language group from pairwise comparison based on LMM.

- Centroid (in Hz) of [f]

Table 69 shows the means and SEs of the centroid of [f] in all contexts based on the numbers of stimuli in each language group - 466 for native English, 530 for native Thai and 1164 for L2 English, Tukey's HSD post-hoc test for language group × gender interaction indicates that in female production, the centroid of native English [f] is significantly lower than the centroid of L2 English [f] with a moderate effect size (b = -994.85, SE = 215.11, df = 76.78, t = -4.63, p < 0.01, d = 0.35) and the centroid of native English [f] is significantly lower than that of native Thai [f] with a moderate effect size (b = -1097.21, SE = 223.31, df = 88.52, t = -4.91, p < 0.01, d = 0.46). The post-hoc test also shows that in male production, the centroid of native Thai [f] is significantly lower than the centroid of L2 English [f] with a small effect size (b = -365.52, SE = 71.59, df = 174.74, t = -5.11, p < 0.01, d = 0.14). Tukey's HSD post-hoc test for the language group × vowel interaction indicates that in the high vowel context, the centroid of native English [f] is significantly lower than the centroid of L2 English [f] with a moderate effect size (b = -788.76, SE = 169.22, df = 79.24, t = -4.66, p < 0.01, d = 0.48) and the centroid of native English [f] is significantly lower than that of native Thai [f] with a moderate effect size (b = -626.11, SE = 184.68, df = 94.79, t = -3.39, p < 0.05, d = 0.41). In the low vowel context, the centroid of native English [f] is significantly lower than that of L2 English [f] with a moderate effect size (b = -625.59, SE =

178.51, *df* = 76.42, *t* = -3.504, *p* < 0.05, *d* = 0.30) and the centroid of native English [f] is significantly lower than the centroid of native Thai [f] with a moderate effect size (*b* = -607.35, *SE* = 193.99, *df* = 95.35, *t* = -3.13, *p* < 0.05, *d* = 0.34). In the back vowel context, the centroid of native English [f] is significantly lower than that of L2 English with a small to moderate effect size (*b* = -501.82, *SE* = 161.42, *df* = 76.88, *t* = -3.109, *p* < 0.05, *d* = 0.26). These results suggest that in female production, L2 English [f] and native Thai [f] are produced with more effort than native English [f] but in male production L2 English [f] is produced with more effort than native Thai [f]. In the high vowel and low vowel contexts, L2 English [f] and native Thai [f] are produced with more effort than native English [f]. In the back vowel context, only L2 English [f] is produced with more effort than native English [f]. Figure 52 and Figure 53 show the patterns supporting the post-hoc tests.

Table 69. Means and SEs of language, language × gender, language × vowel, language × gender × vowel for the centroid of [f] from pairwise comparison based on LMM

		L2 English		Native English		Native Thai	
		Mean	SE	Mean	SE	Mean	SE
Language	Overall	11143.80	84.04	10505.08	130.51	11012.22	92.15
Language × Gender	Male	10851.09	122.08	10568.49	184.26	10485.57	132.65
	Female	11436.52	112.89	10441.67	184.45	11538.87	125.06
Language × Vowel context	High vowel	11209.69	97.25	10420.92	147.14	11047.04	111.61
	Low vowel	11105.84	100.31	10480.26	153.80	11087.61	118.22
	Back vowel	11115.88	91.68	10614.05	139.64	10902.03	111.63
Language × Vowel context × Gender	Male-high	10934.42	135.42	10501.78	198.61	10537.84	149.80
	Male-low	10835.49	140.90	10566.03	205.28	10583.32	158.05
	Male-back	10783.36	129.57	10637.66	192.24	10335.57	148.63
	Female-high	11484.95	126.28	10340.07	199.03	11556.24	142.80
	Female-low	11376.20	130.87	10394.48	205.70	11591.89	150.51
	Female-back	11448.40	120.32	10590.45	192.25	11468.48	141.76

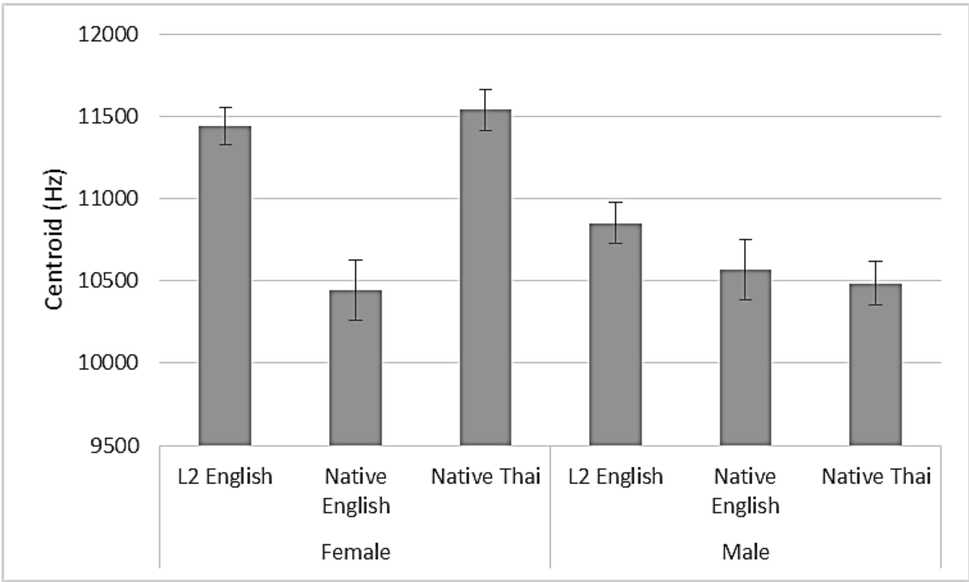

Figure 52. Means of centroid (Hz) for [f] according to language group × gender from pairwise comparison based on LMM

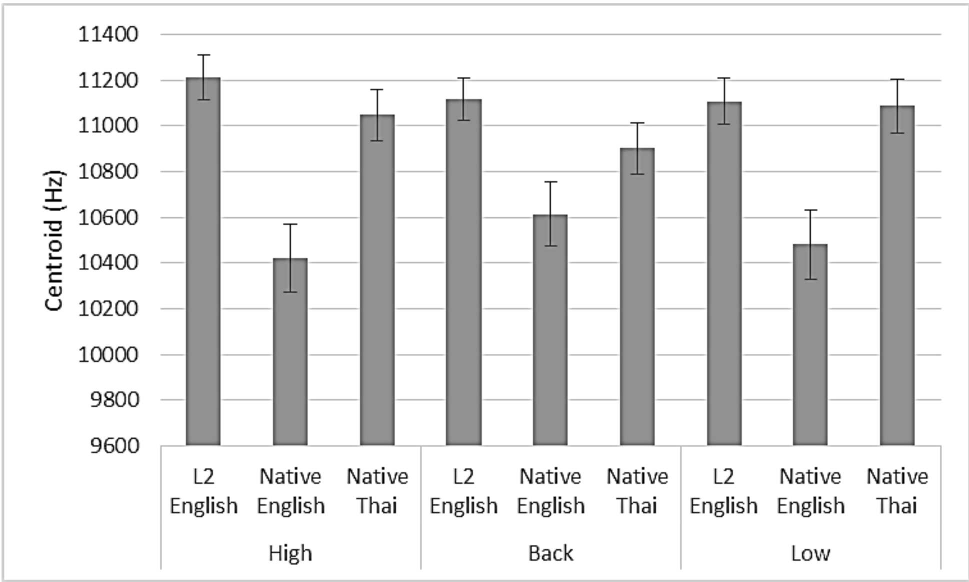

Figure 53. Means of centroid (Hz) for [f] according to language group × vowel context from pairwise comparison based on LMM

- SD (in Hz) of [f]

Table 70 shows the means and SEs in all contexts for the SD of [f] based on the numbers of stimuli in each language group - 465 for native English, 531 for native Thai and 1162 for L2 English. Tukey's HSD post-hoc test for the language group × gender interaction indicates that in female production, the SD of native English [f] is significantly higher than that of L2 English [f] with a moderate effect size (*b*

= 446.02, *SE* = 114.73, *df* = 77.85, *t* = 3.89, *p* < 0.01, *d* = 0.30) and the SD of native English [f] is significantly higher than that SD of native Thai [f] with a moderate effect size (*b* = 466.32, *SE* = 118.73, *df* = 89.08, *t* = 3.93, *p* < 0.01, *d* = 0.37). Tukey's HSD post-hoc test for the language group × vowel interaction indicate that in the high vowel context, the SD of native English [f] is significantly higher than that of L2 English [f] with a moderate effect size (*b* = 463.72, *SE* = 96.16, *df* = 78.43, *t* = 4.82, *p* < 0.01, *d* = 0.52) and the SD of native English [f] is significantly higher than the SD of native Thai [f] with a moderate effect size (*b* = 420.85, *SE* = 102.30, *df* = 91.76, *t* = 4.11, *p* < 0.01, *d* = 0.50).

The post-hoc test also shows similar patterns in the low vowel context for the SD of native English [f] as it is significantly higher than that of L2 English [f] with a moderate effect size (*b* = 314.34, *SE* = 93.78, *df* = 76.63, *t* = 3.35, *p* < 0.05, *d* = 0.30) and the SD of native English [f] is significantly higher than the SD of native Thai [f] with a moderate effect size (*b* = 369.36, *SE* = 100.50, *df* = 94.04, *t* = 3.68, *p* < 0.05, *d* = 0.40). These results suggest that in female production, in the high vowel context and low vowel context, native English [f] is produced with more effort than in native Thai [f] or L2 English [f]. Figure 54 and Figure 55 show the patterns supporting the post-hoc tests.

Table 70. Means and SEs of language, language × gender, language × vowel, language × gender × vowel for the SD of [f] from pairwise comparison based on LMM

		L2 English		Native English		Native Thai	
		Mean	SE	Mean	SE	Mean	SE
Language	Overall	2707.78	44.43	3024.45	69.62	2710.53	48.81
Language × Gender	Male	2748.22	64.98	2935.54	98.15	2774.02	70.71
	Female	2667.34	59.97	3113.36	98.24	2647.05	66.67
Language × Vowel context	High vowel	2713.31	52.74	3177.03	82.07	2756.18	61.07
	Low vowel	2774.04	51.32	3088.38	79.78	2719.02	61.12
	Back vowel	2635.99	46.80	2807.95	72.76	2656.40	57.54
Language × Vowel context × Gender	Male-high	2774.10	74.71	3108.47	109.26	2840.02	82.76
	Male-low	2791.25	73.21	2976.24	107.50	2759.28	82.40
	Male-back	2679.31	67.31	2721.92	100.95	2722.77	77.60
	Female-high	2652.53	69.29	3245.59	109.64	2672.35	78.74
	Female-low	2756.83	67.66	3200.52	107.55	2678.76	78.60
	Female-back	2592.67	62.33	2893.98	101.00	2590.03	73.95

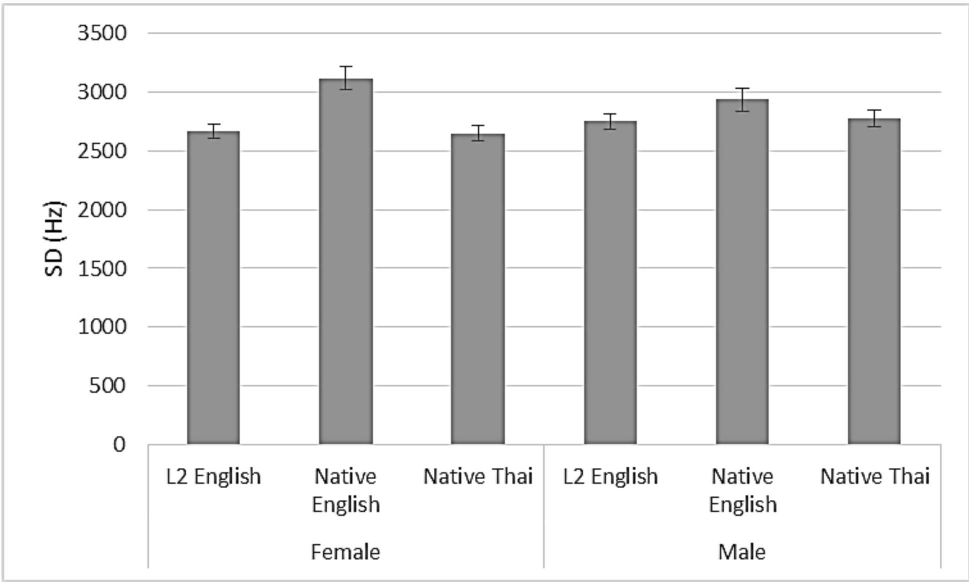

Figure 54. Means of SD (Hz) for [f] according to language group × gender from pairwise comparison based on LMM

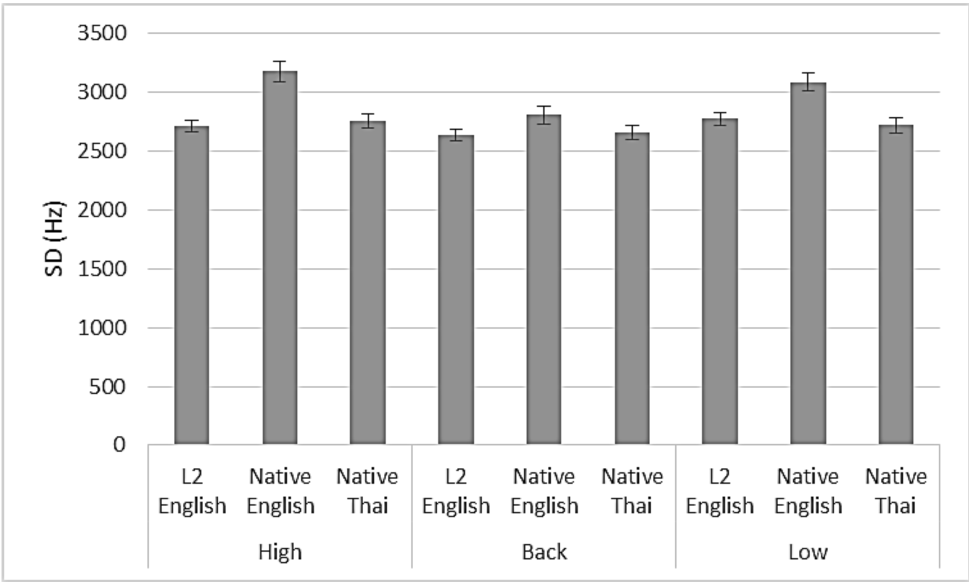

Figure 55. Means of SD (Hz) for [f] according to language group × vowel context from pairwise comparison based on LMM

- Skewness of [f]

Table 71 shows means and SEs for skewness of [f] in all contexts based on the numbers of stimuli in each language group - 464 for native English, 502 for native Thai and 1155 for L2 English. Tukey's HSD post-hoc test indicates no significant differences in any pairs ($p > 0.05$ for all contrasts) even though Tukey's HSD post-hoc test for the language group × gender interaction indicates tendency of skewness of native Thai [f] to be lower than that of L2 English in female production (p = 0.06).

Table 71. Means and SEs of language, language × gender, language × vowel, language × gender × vowel for the skewness of [f] from pairwise comparison based on LMM

		L2 English		Native English		Native Thai	
		Mean	SE	Mean	SE	Mean	SE
Language	Overall	-0.59	0.03	-0.54	0.05	-0.60	0.04
Language × Gender	Male	-0.50	0.05	-0.48	0.07	-0.43	0.06
	Female	-0.69	0.05	-0.60	0.07	-0.78	0.05
Language × Vowel context	High vowel	-0.64	0.04	-0.55	0.06	-0.61	0.05
	Low vowel	-0.62	0.04	-0.55	0.06	-0.69	0.05
	Back vowel	-0.53	0.04	-0.53	0.07	-0.51	0.06
Language × Vowel context × Gender	Male-high	-0.55	0.06	-0.49	0.08	-0.44	0.07
	Male-low	-0.54	0.06	-0.50	0.08	-0.53	0.07
	Male-back	-0.42	0.06	-0.45	0.09	-0.31	0.07
	Female-high	-0.72	0.05	-0.61	0.08	-0.79	0.06
	Female-low	-0.69	0.05	-0.59	0.08	-0.86	0.06
	Female-back	-0.64	0.06	-0.61	0.09	-0.70	0.07

- Kurtosis for [f]

Table 72 Thai and 1154 for L2 English. Tukey's HSD post-hoc test indicates that the kurtosis of native Thai [f] is significantly higher than that of L2 English [f] with a small to moderate effect size (b = 0.25, SE = 0.10, df = 90.15, t = 2.49, $p < 0.05$, d = 0.31). It also shows that the kurtosis of native English [f] is significantly lower than that of native Thai [f] with a small effect size (b = -0.52, SE = 0.24, df = 94.1, t = -2.19, $p < 0.05$, d = 0.06). These results suggest that native Thai [f] is produced with more effort than L2 English [f] and native English [f]. Figure 56 illustrates that in this case, the kurtosis of native Thai [f] is significantly higher than that of L2 English [f] and native English [f].

Table 72. Means and SEs of language, language × gender, language × vowel, language × gender × vowel for the kurtosis of [f] from pairwise comparison based on LMM

		L2 English		Native English		Native Thai	
		Mean	SE	Mean	SE	Mean	SE
Language	Overall	1.00	0.12	0.73	0.19	1.25	0.15
Language × Gender	Male	0.83	0.17	0.56	0.22	1.08	0.18
	Female	1.17	0.15	0.90	0.22	1.42	0.17
Language × Vowel context	High vowel	1.02	0.15	0.75	0.21	1.27	0.17
	Low vowel	0.91	0.12	0.63	0.19	1.16	0.15
	Back vowel	1.07	0.14	0.80	0.20	1.32	0.16
Language × Vowel context × Gender	Male-high	0.86	0.18	0.58	0.23	1.11	0.20
	Male-low	0.74	0.16	0.46	0.22	0.99	0.18
	Male-back	0.91	0.17	0.63	0.22	1.56	0.19
	Female-high	1.19	0.18	0.92	0.23	1.44	0.19
	Female-low	1.08	0.15	0.80	0.22	1.33	0.17
	Female-back	1.24	0.17	0.97	0.22	1.49	0.18

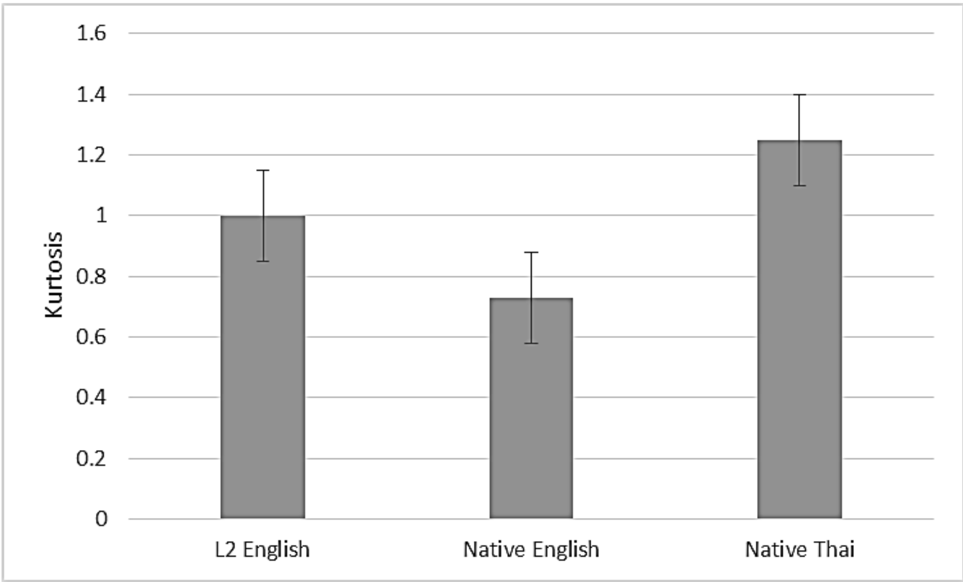

Figure 56. Means of kurtosis for [f] according to language group from pairwise comparison based on LMM

- Normalised amplitude of [f]

Table 73: Mean and SD of noise amplitude and vowel amplitude (in dB, averaged across vowels) in two genders for [f]

Language	**Gender**	**Noise amplitude**	**Vowel amplitude**
L2 English	Female	67.77 (5.28)	76.55 (4.39)
	Male	71.34 (5.15)	79.05 (3.69)
Native English	Female	65.78 (4.40)	73.72 (4.17)
	Male	69.84 (4.98)	79.53 (4.18)
Native Thai	Female	69.65 (4.77)	77.99 (5.18)
	Male	73.26 (3.81)	79.76 (5.50)

Table 73 shows means and SDs in all contexts of the normalised amplitude for [f] based on the numbers of stimuli in each language group - 469 for native

English, 534 for native Thai and 1183 for L2 English. Table 74 shows the means and SEs in all contexts. Tukey's HSD post-hoc test for the language × gender interaction indicates that in female production, no significant differences in language pairs are found ($p > 0.05$ for all contrasts); however, in male production:

- the normalised amplitude of native Thai [f] is significantly higher than the normalised amplitude of L2 English [f] with a small effect size ($b = 1.11$, $SE = 0.30$, $df = 64.12$, $t = 3.73$, $p < 0.01$, $d = 0.17$);
- the normalised amplitude of native English [f] is significantly lower than that of L2 English [f] with a moderate effect size ($b = -1.99$, $SE = 0.47$, $df = 82.43$, $t = -4.19$, $p < 0.01$, $d = 0.29$);
- the normalised amplitude of native English [f] is significantly lower than that of native Thai [f] with a moderate effect size ($b = -3.09$, $SE = 0.54$, $df = 114.83$, $t = -5.68$, $p < 0.01$, $d = 0.51$).

Tukey's HSD post-hoc test for the language × vowel interaction indicates that in the high vowel context, the normalised amplitude of native English [f] is significantly lower than that of native Thai [f] with a moderate effect size ($b = -1.97$, $SE = 0.56$, $df = 68.52$, $t = -3.49$, $p < 0.05$, $d = 0.40$) and the normalised amplitude of native Thai [f] is significantly higher than that of L2 English [f] with a moderate effect size ($b = 1.45$, $SE = 0.46$, $df = 31.99$, $t = 3.13$, $p < 0.05$, $d = 0.26$). In the low vowel context, the normalised amplitude of native English [f] is significantly lower than that of native Thai [f] with a moderate effect size ($b = -1.74$, $SE = 0.55$, $df = 76.19$, $t = -3.17$, $p < 0.05$, $d = 0.34$).

These results suggest that in male production native English [f] is the produced with the least effort, followed by L2 English [f] and native Thai [f] respectively. In the high vowel context, native English [f] and L2 English [f] are produced with less effort than native Thai [f] and in the low vowel context, native English [f] is produced with less effort than native Thai [f]. Figure 57 and Figure 58 illustrate the results of the pairwise comparisons for language × gender and language × vowel interactions.

Table 74. Means and SEs of language, language × gender, language × vowel, language × gender × vowel for the normalised amplitude of [f] from pairwise comparison based on LMM

		L2 English		Native English		Native Thai	
		Mean	SE	Mean	SE	Mean	SE
Language	Overall	-14.69	0.32	-14.73	0.42	-14.17	0.36
Language × Gender	Male	-14.55	0.40	-15.51	0.54	-13.88	0.44
	Female	-14.82	0.38	-13.94	0.54	-14.47	0.42
Language × Vowel context	High vowel	-14.92	0.50	-14.91	0.56	-13.70	0.52
	Low vowel	-13.87	0.48	-14.41	0.58	-13.08	0.55
	Back vowel	-15.27	0.46	-14.86	0.57	-15.74	0.55
Language × Vowel context × Gender	Male-high	-14.88	0.55	-15.79	0.66	-13.50	0.58
	Male-low	-13.83	0.55	-15.29	0.69	-12.87	0.63
	Male-back	-14.95	0.54	-15.46	0.67	-15.26	0.62
	Female-high	-14.96	0.53	-14.03	0.65	-13.90	0.57
	Female-low	-13.91	0.53	-13.53	0.69	-13.29	0.61
	Female-back	-15.59	0.52	-14.26	0.67	-16.22	0.61

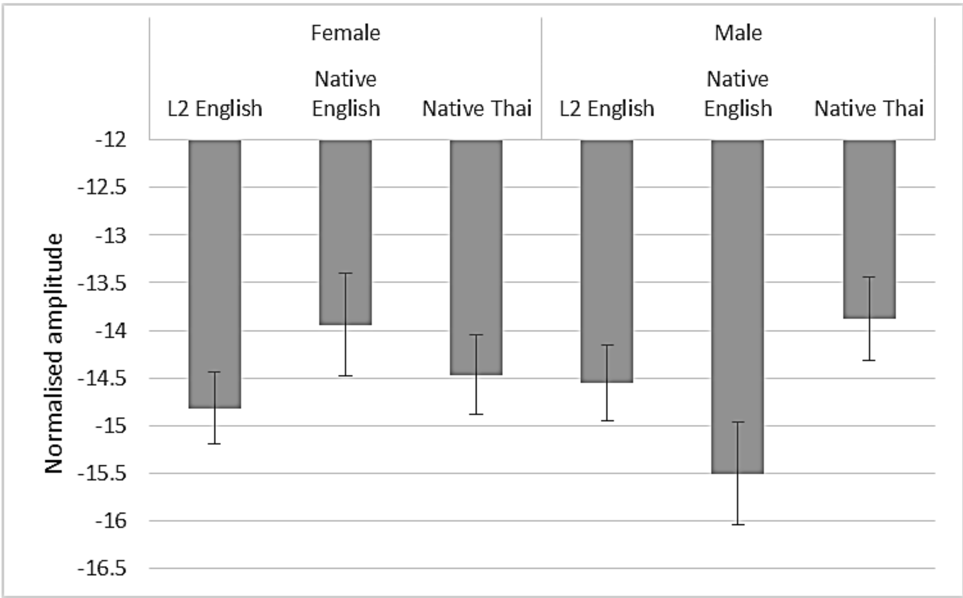

Figure 57. Means of normalised amplitude for [f] according to language group × gender from pairwise comparison based on LMM

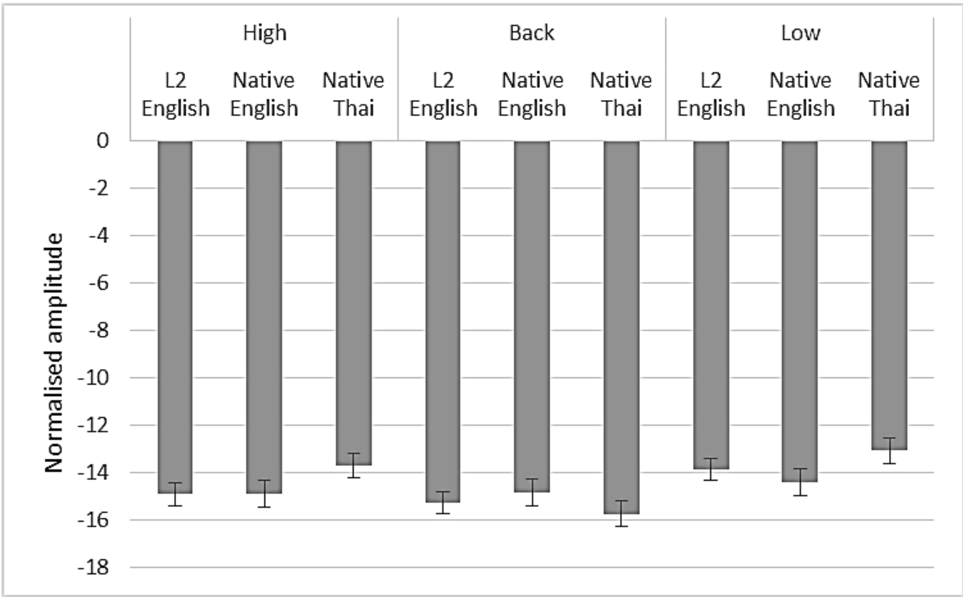

Figure 58. Means of normalised amplitude for [f] according to language group × vowel from pairwise comparison based on LMM

- Onset F2 frequency of [f]

Table 75 shows the means and SEs for onset F2 frequency in all contexts based on the numbers of stimuli in each language group - 474 for native English, 485 for native Thai and 1157 for L2 English. Tukey's HSD post-hoc test for the language × gender × vowel interaction indicates that for the back vowel context in female production, the onset F2 frequency of native English [f] is significantly higher than that of native Thai [f] with a moderate effect size (b = 297.14, SE = 83.11, df = 34.14, t = 3.58, p < 0.05, d = 0.58) and L2 English [f] with a moderate effect size (b = 191.38 SE = 20.05, df = 83.00, t = 9.55, p < 0.01, d = 0.28), indicating that native English [f] is produced with more effort than native Thai [f] and L2 English [f] in this context. However, in the back vowel context in male production, the onset F2 frequency of native English [f] is only significantly higher than that of L2 English [f] with a moderate effect size (b = 171.29, SE = 20.60, df = 84.42, t = 8.31, p < 0.01, d = 0.26), suggesting that in this context, native English [f] is only produced with more effort than L2 English [f]. In back vowel context in male production, the onset F2 frequency of native English [f] has tendency to be significantly higher than that of native Thai [f] (p = 0.06), and in low vowel context in female production, the onset F2 frequency of native English [f] has tendency to be significantly lower than that of L2 English [f] (p = 0.05). Figure 59 illustrates that in the back vowel context in female production, onset F2 frequency is higher for native English [f] than native Thai [f] and L2 English [f], whereas in the back vowel context in male production, the onset F2 frequency of native English [f] is only higher than that of L2 English [f].

Table 75. Means and SEs of language, language × gender, language × vowel, language × gender × vowel for the onset F2 frequency of [f] from pairwise comparison based on LMM

		L2 English		Native English		Native Thai	
		Mean	SE	Mean	SE	Mean	SE
Language	Overall	1514.05	33.74	1555.66	36.56	1434.70	37.88
Language × Gender	Male	1424.72	35.94	1458.55	40.85	1362.90	40.44
	Female	1603.38	35.38	1652.77	40.83	1506.50	39.93
Language × Vowel context	High vowel	2065.11	64.51	2093.89	68.94	2141.41	65.51
	Low vowel	1466.38	55.58	1381.10	59.08	1259.70	64.44
	Back vowel	1010.65	50.19	1191.99	51.13	902.98	63.00
Language × Vowel context × Gender	Male-high	1949.71	68.01	1908.83	75.75	2043.13	69.84
	Male-low	1351.33	58.30	1322.40	64.55	1182.02	67.63
	Male-back	973.11	50.76	1144.41	52.56	863.54	64.80
	Female-high	2180.52	67.06	2278.94	75.79	2239.69	69.03
	Female-low	1581.44	57.56	1439.81	64.41	1337.37	67.17
	Female-back	1048.19	50.82	1239.57	52.50	942.43	64.43

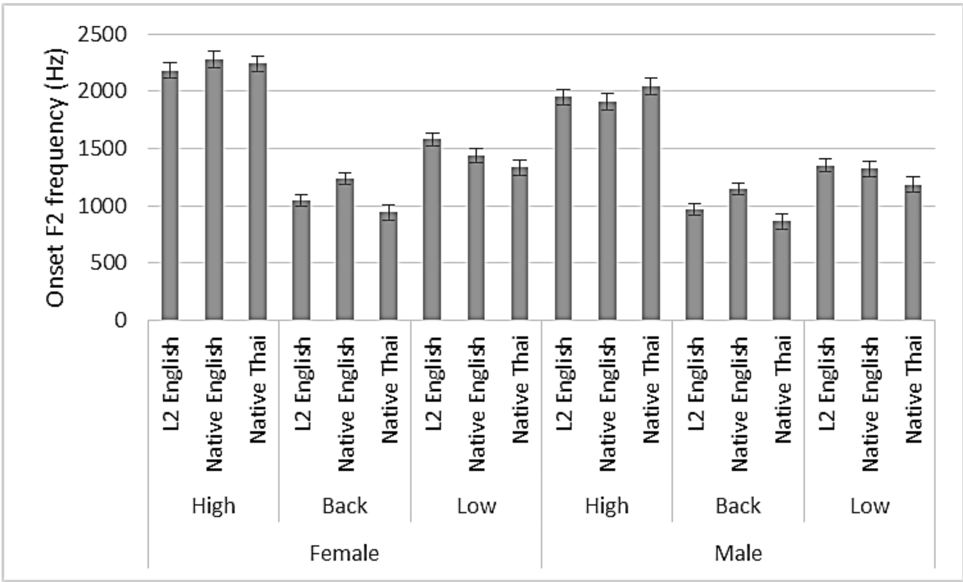

Figure 59. Means of onset F2 frequency (Hz) for [f] according to language group × vowel context × gender produced from pairwise comparison based on LMM

Table 76 shows the overall interpretation of the acoustic measurements exhibiting significant differences for L2 English [f]. Phonetic properties of L2 English [f] in many contexts: overall in peak location and kurtosis, female production in centroid and SD and male production in centroid and normalised amplitude, high vowel context in centroid, SD and normalised amplitude, low vowel context in centroid and SD and normalised amplitude and back vowel context in centroid, and back vowel context in both genders' production in onset F2 frequency confirms the SLM prediction that L2 [f] acoustic patterns would be different from those of native English [f].

Table 76. Interpretation of significant acoustic measurements for L2 English [f]

Position	Measurement	Order	Interpretation	Overall conclusion
Overall	Peak location	L2 > T, E	L2 English [f] is produced with more effort than native Thai [f] and native English [f]	Two possibilities: 1) L2 English [f] is produced with more effort than native Thai [f] and native English [f]; 2) native Thai [f] is produced with more effort than L2 English [f] and native English [f]
	Kurtosis	T > L2, E	Native Thai [f] is produced with more effort than L2 English [f] and native English [f]	
Female	Centroid	L2, T > E	L2 English [f] and native Thai [f] are produced with more effort than native English [f]	Two possibilities for female production: 1) L2 English [f] and native Thai [f] are produced with more effort than native English [f]; 2) native English [f] is produced with more effort than L2 English [f] and native Thai [f]
	SD	E > L2, T	Native English [f] is produced with more effort than L2 English [f] and native Thai [f]	
Male	Centroid	L2 > T	L2 English [f] is produced with more effort than native Thai [f]	Two possibilities for male production: 1) L2 English [f] is produced with more effort than native Thai [f]; 2) native Thai [f] is produced with the most effort, followed by L2 English [f] and native English [f]
	Normalised amplitude	T > L2 > E	Native Thai [f] is produced with the most effort, followed by L2 English [f] and native English [f]	
High vowel	Centroid	L2, T > E	L2 English [f] and native Thai [f] are produced with more effort than native English [f]	Three possibilities for high vowel context: 1) L2 English [f] and native Thai [f] are produced with more effort than native English [f]; 2) native English [f] is produced with more effort than L2 English [f] and native Thai [f]; and 3) native Thai [f] is produced with more effort than native English [f] and L2 English [f]
	SD	E > L2, T	Native English [f] is produced with more effort than L2 English [f] and native Thai [f]	
	Normalised amplitude	T > E, L2	Native Thai [f] is produced with more effort than native English [f] and L2 English [f]	
Low vowel	Centroid	L2, T > E	L2 English [f] and native Thai [f] are produced with more effort than native English [f]	Two possibilities for low vowel context: 1) L2 English [f] and native Thai [f] are produced with more effort than native English [f]; 2) native English [f] is produced with more effort than L2 English [f] and native Thai [f]
	SD	E > L2, T	Native English [f] is produced with more effort than L2 English [f] and native Thai [f]	
	Normalised amplitude	T > E	Native Thai [f] is produced with more effort than native English [f]	
Back vowel	Centroid	L2 > E	L2 English [f] is produced with more effort than native English [f]	In back vowel context, L2 English [f] is produced with more effort than native English [f]
Back vowel female	F2	E > T, L2	Native English [f] involves higher effort than native Thai [f] and L2 English [f]	In back vowel context for females, native English [f] involves higher effort than native Thai [f] and L2 English [f]
Back vowel male	F2	E > L2	Native English [f] involves higher effort than L2 English [f]	In back vowel context for males, native English [f] involves higher effort than L2 English [f]

L2 English [s]

The acoustic characteristics of L2 English [s] were compared to native Thai [s] and native English [s]. The results are set out below.

- Peak location (in Hz) of [s]

Concerning peak location for [s], Table 77 shows the means and SEs in all contexts based on the numbers of stimuli in each language group - 478 for native English, 531 for native Thai and 1137 for L2 English. Tukey's HSD post-hoc test indicates significant differences in all contrasts:

1) The peak location of L2 English [s] is significantly higher than the peak location of native English [s] with a small effect size (b = 853.44, SE = 261.34, df = 75.26, t = 3.27, p < 0.01, d = 0.14).

2) The peak location of L2 English [s] is significantly lower than the peak location of native Thai [s] with a small effect size (b = -464.77, SE = 83.78, df = 65.25, t = -5.55, p < 0.01, d = 0.08).

3) The peak location of native English [s] is significantly lower than the peak location of native Thai [s] with a moderate effect size (b = -1318.21, SE = 268.82, df = 83.19, t = -4.90, p < 0.01, d = 0.26).

These results suggest that native Thai [s] is the most fronted, followed by L2 English [s] and native English [s], respectively. This result also suggests that L2 Thai learners notice the subtle differences between native Thai [s] and native English [s], and they produce the L2 English [s] in a different manner from when producing native Thai [s]. Figure 60 shows that all language pairs are different in all contexts.

Table 77. Means and SEs of language, language × gender, language × vowel, language × gender × vowel for the peak location of [s] from pairwise comparison based on LMM

		L2 English		Native English		Native Thai	
		Mean	SE	Mean	SE	Mean	SE
Language	Overall	8539.03	138.49	7685.589	219.63	9003.796	151.86
Language × Gender	Male	7765.64	187.84	6912.20	249.18	8230.40	197.47
	Female	9312.42	175.72	8458.98	249.37	9777.19	186.90
Language × Vowel context	High vowel	8631.06	145.87	7777.62	224.67	9095.82	157.39
	Low vowel	8647.84	141.53	7794.40	222.08	9112.60	155.49
	Back vowel	8338.20	158.38	7484.76	231.88	8802.96	170.55
Language × Vowel context × Gender	Male-high	7857.66	193.31	7004.22	253.61	8322.43	201.72
	Male-low	7874.44	190.11	7021.00	251.36	8339.21	200.29
	Male-back	7564.80	202.96	6711.36	260.05	8029.57	212.18
	Female-high	9404.45	181.63	8551.01	253.85	9869.22	191.46
	Female-low	9421.23	178.10	8567.79	251.52	9886.00	189.84
	Female-back	9111.59	191.77	8258.15	260.22	9576.36	202.37

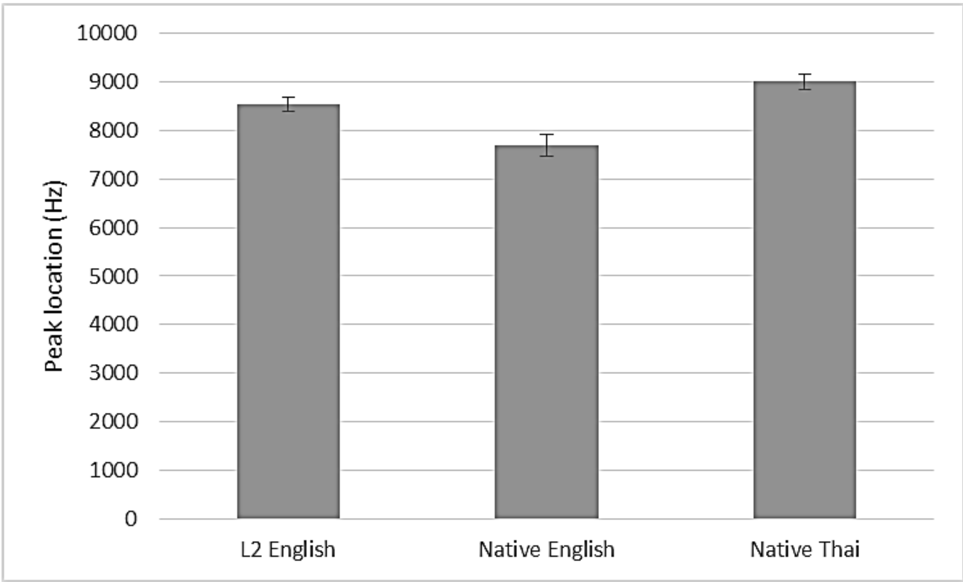

Figure 60. Means of peak location (Hz) for [s] according to language group from pairwise comparison based on LMM

- Centroid (in Hz) of [s]

With regard to the centroid for [s], Table 78 shows the means and SEs in all contexts based on the numbers of stimuli in each language group - 480 for native English, 532 for native Thai and 1133 for L2 English. Tukey's HSD post-hoc test for the language × gender interaction indicates that in female production, the centroid of L2 English [s] is significantly lower than that of native Thai [s] with a small effect size (b = -446.51, SE = 64.20, df = 103.15, t = -6.95, p < 0.01, d = 0.10) and the centroid of native English [s] is significantly lower than that of native Thai [s] with a moderate effect size (b = -988.34, SE = 289.12, df = 80.04, t = -3.42, p < 0.01, d = 0.26). In male production, the post-hoc test indicates that:

- the centroid of L2 English [s] is significantly higher than that of native English [s] with a small effect size (b = 897.33, SE = 291.05, df = 75.09, t = 3.08, p < 0.05, d = 0.19).
- the centroid of L2 English [s] is significantly lower than that of native Thai [s] with a small effect size (b = -333.32, SE = 63.88, df = 101.06, t = -5.22, p < 0.01, d = 0.08).
- the centroid of native English [s] is significantly lower than that of native Thai [s] with a moderate effect size (b = -1230.66, SE = 295.33, df = 79.36, t = -4.17, p < 0.01, d = 0.31).

Tukey's HSD post-hoc test for the language × vowel interaction indicates that in the high vowel context, the centroid of L2 English [s] is significantly higher than that of native English [s] with a moderate effect size (b = 707.10, SE = 207.50, df = 77.83, t = 3.41, p < 0.05, d = 0.29) but lower than that of native Thai [s] with a small effect size (b = -315.09, SE = 85.89, df = 28.29, t = -3.67, p < 0.01, d = 0.14). Also, in the high vowel context, the centroid of native English [s] is significantly lower than the centroid of native Thai [s] with a moderate effect size (b = -1022.20, SE = 218.26, df = 86.61, t = -4.68, p < 0.01, d = 0.50). In the low vowel context, the centroid of L2 English [s] is significantly lower than the centroid of native Thai [s] with a small effect size (b = -325.75, SE = 78.63, df = 29.69, t = -4.14, p < 0.01, d = 0.11) but higher than that of native English [s] with a moderate effect size (b = 841.55, SE = 209.60, df = 76.09, t = 4.01, p < 0.01, d = 0.27). In the low vowel context, the centroid of native English [s] is significantly lower than the centroid of native Thai [s] with a moderate effect size (b = -1167.30, SE = 219.67, df = 86.13, t = -5.31, p < 0.01, d = 0.45). The post-hoc test also shows that in back vowel context, the centroid of native Thai [s] is significantly higher than that of L2 English [s] with a small effect size (b = 528.90, SE = 81.37, df = 32.85, t = 6.50, p < 0.01, d = 0.18) and that of native English [s] with a moderate effect size (b = 1139.00, SE = 225.34, df = 85.76, t = 5.05, p < 0.01, d = 0.43).

These results suggest that in female production, native Thai [s] is more fronted than L2 English [s] and native English [s], whereas in male production native Thai [s] is the most fronted, followed by L2 English [s] and native English [s] respectively. In the high and low vowel contexts, native Thai [s] is the most fronted, followed by L2 English [s] and native English [s], respectively, but in the back vowel context, native Thai [s] is more fronted than L2 English [s] and native English [s]. Figure 61 and Figure 62 shows the patterns of the post-hoc tests.

Table 78. Means and SEs of language, language × gender, language × vowel, language × gender × vowel for the centroid of [s] from pairwise comparison based on LMM

		L2 English		Native English		Native Thai	
		Mean	SE	Mean	SE	Mean	SE
Language	Overall	9003.26	109.66	8283.68	170.80	9393.18	113.49
Language × Gender	Male	8432.56	160.16	7535.22	242.88	8765.88	165.26
	Female	9573.97	148.08	9032.14	242.88	10020.48	154.31
Language × Vowel context	High vowel	9126.85	118.49	8419.75	179.75	9441.94	123.79
	Low vowel	9102.67	117.16	8261.12	180.01	9428.42	125.90
	Back vowel	8780.27	120.26	8170.17	184.25	9309.17	129.74
Language × Vowel context × Gender	Male-high	8477.34	167.53	7592.49	250.21	8735.84	173.15
	Male-low	8524.26	167.79	7504.96	250.69	8793.42	176.27
	Male-back	8296.07	171.38	7508.22	254.70	8768.37	180.46
	Female-high	9776.36	155.77	9247.01	250.21	10148.05	163.06
	Female-low	9681.07	155.46	9017.28	250.69	10063.41	165.64
	Female-back	9264.48	159.44	8832.13	254.70	9849.97	169.87

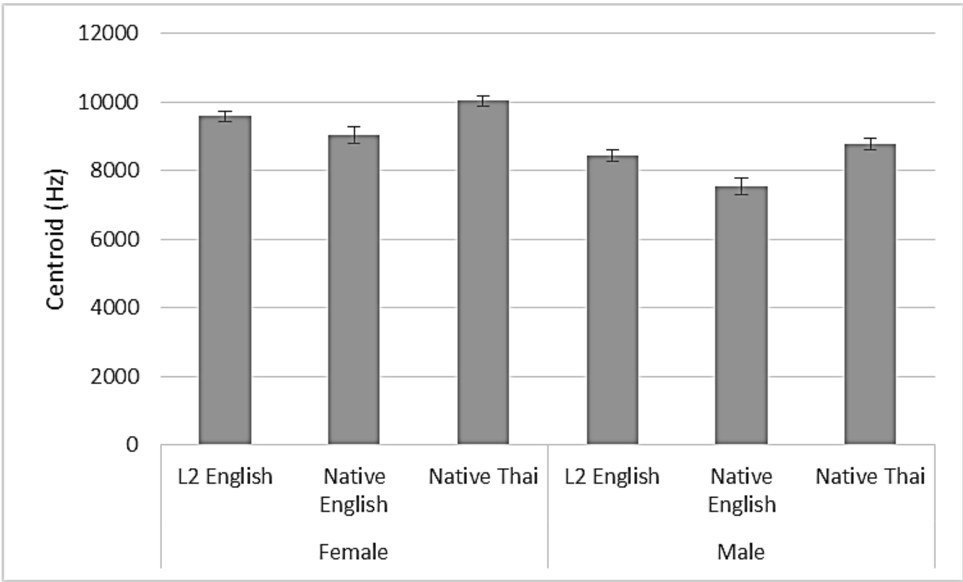

Figure 61. Mean of centroid (Hz) for [s] according to language group × gender from pairwise comparison based on LMM

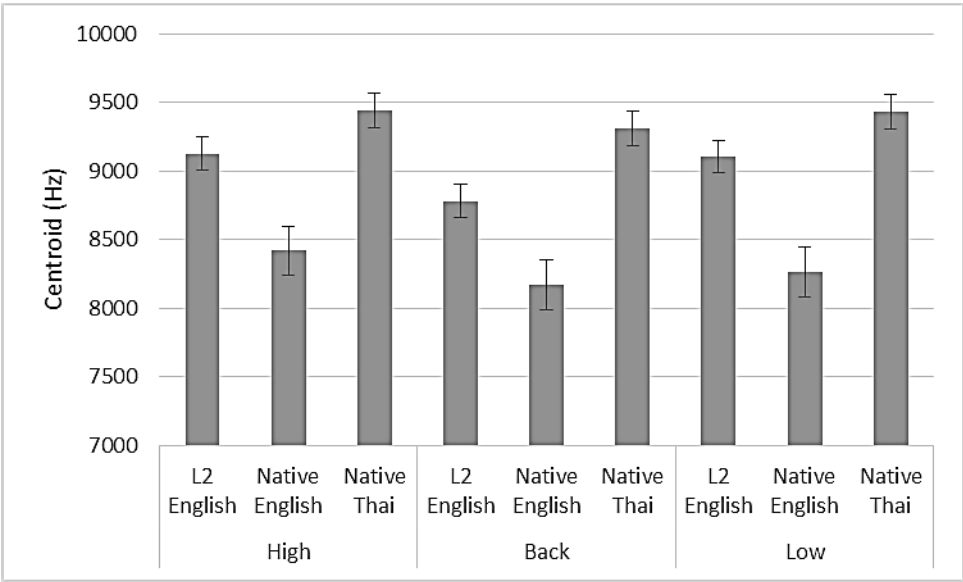

Figure 62. Mean of centroid (Hz) for [s] according to language group × vowel context from pairwise comparison based on LMM

- SD (in Hz) of [s]

Table 79 shows means and SEs in all contexts for SD in relation to [s] based on the numbers of stimuli in each language group - 478 for native English, 531 for native Thai and 1133 for L2 English. Tukey's HSD post-hoc test shows no significant differences in language pairs (p > 0.05 for all contrasts).

Table 79. Means and SEs of language, language × gender, language × vowel, language × gender × vowel for the SD of [s] from pairwise comparison based on LMM

		L2 English		Native English		Native Thai	
		Mean	SE	Mean	SE	Mean	SE
Language	Overall	2012.30	45.99	2018.93	72.97	1998.26	48.43
Language × Gender	Male	2167.37	62.40	2174.00	82.80	2153.33	64.13
	Female	1857.23	58.36	1863.86	82.84	1843.19	60.41
Language × Vowel context	High vowel	1928.94	47.22	1935.57	74.08	1914.90	49.30
	Low vowel	1931.94	48.44	1938.57	74.38	1917.90	50.96
	Back vowel	2176.03	50.16	2182.66	75.50	2161.99	52.51
Language × Vowel context × Gender	Male-high	2084.01	63.28	2090.64	83.76	2069.97	64.75
	Male-low	2087.01	64.26	2093.64	84.07	2072.97	66.09
	Male-back	2331.10	65.53	2337.73	85.04	2317.06	67.26
	Female-high	1773.87	59.38	1780.50	83.85	1759.83	61.14
	Female-low	1776.87	60.29	1783.49	84.06	1762.83	62.42
	Female-back	2020.96	61.70	2027.58	85.07	2006.92	63.72

- Skewness of [s]

For the skewness of [s], Table 80 shows the means and SEs in all contexts based on the numbers of stimuli in each language group - 462 for native English, 509 for native Thai and 1121 for L2 English. Tukey's HSD post-hoc test for the language × gender shows that in female production, the skewness of L2 English [s] is significantly higher than that of native Thai [s] with a small effect size (b = 0.18, SE = 0.04, df = 214.95, t = 4.18, p < 0.01, d = 0.11), suggesting that native Thai [s] is more fronted than L2 English [s] in female production. In male production, the skewness of native English [s] has tendency to be significantly higher than that of native Thai [s] (p = 0.06). Tukey's HSD post-hoc test for the language × vowel interaction indicates that in the high vowel context, the skewness of L2 English [s] is significantly higher than that of native Thai [s] with a small effect size (b = 0.19, SE = 0.05, df = 36.94, t = 3.66, p < 0.01, d = 0.19), suggesting that native Thai [s] is more fronted than L2 English [s]. In high vowel context, the skewness of native English [s] has tendency to be significantly higher than that of native Thai [s] (p = 0.09). In the low vowel context, the skewness of native Thai [s] is significantly lower than that of L2 English [s] with a small effect size (b = 0.17, SE = 0.05, df = 47.46, t = 3.60, p < 0.01, d = 0.14) and that of native English [s] with a moderate effect size (b = 0.39, SE = 0.10, df = 91.07, t = 3.89, p < 0.01, d = 0.33), indicating that in native Thai [s] is more fronted than L2 English [s] and native English [s]. Figure 63 and Figure 64 illustrate skewness in all contexts.

Table 80. Means and SEs of language, language × gender, language × vowel, language × gender × vowel for the skewness of [s] from pairwise comparison based on LMM

		L2 English		Native English		Native Thai	
		Mean	SE	Mean	SE	Mean	SE
Language	Overall	0.54	0.04	0.66	0.06	0.42	0.05
Language × Gender	Male	0.61	0.06	0.81	0.09	0.54	0.07
	Female	0.47	0.05	0.50	0.09	0.29	0.06
Language × Vowel context	High vowel	0.59	0.05	0.67	0.08	0.41	0.06
	Low vowel	0.59	0.05	0.80	0.08	0.41	0.06
	Back vowel	0.44	0.04	0.50	0.06	0.43	0.06
Language × Vowel context × Gender	Male-high	0.70	0.07	0.87	0.10	0.57	0.08
	Male-low	0.64	0.07	0.95	0.10	0.53	0.08
	Male-back	0.47	0.06	0.62	0.09	0.51	0.07
	Female-high	0.49	0.07	0.47	0.10	0.25	0.08
	Female-low	0.53	0.07	0.65	0.10	0.30	0.08
	Female-back	0.41	0.06	0.38	0.09	0.34	0.07

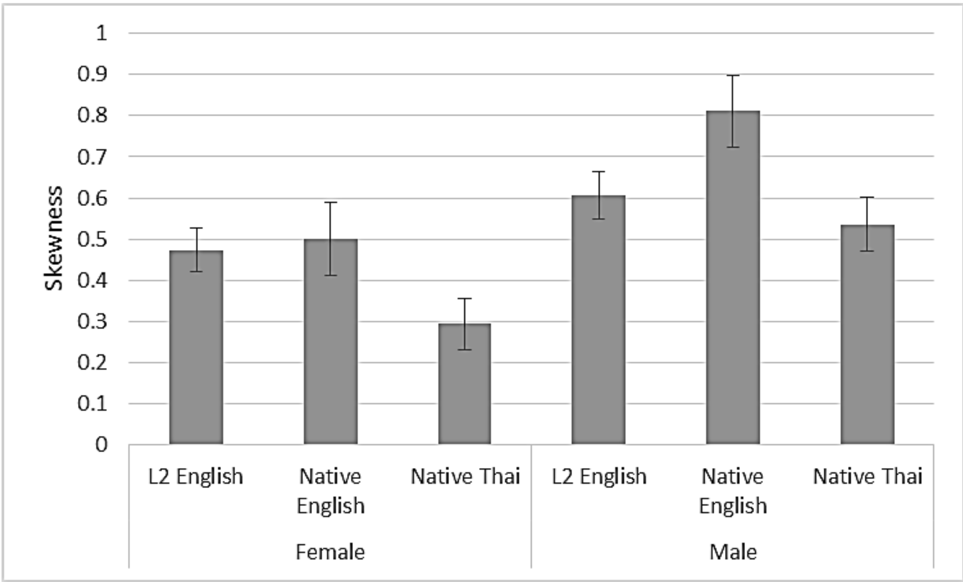

Figure 63. Means of skewness for [s] according to language group × gender from pairwise comparison based on LMM

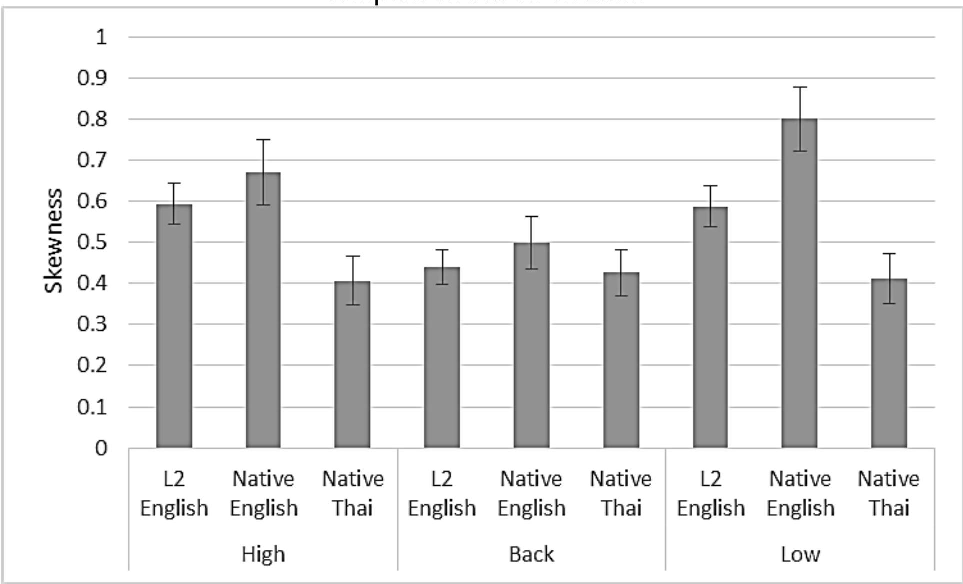

Figure 64. Means of skewness for [s] according to language group × vowel context from pairwise comparison based on LMM

- Kurtosis of [s]

For the kurtosis of [s], Table 81 shows the means and SDs in all contexts based on the numbers of stimuli in each language group - 469 for native English, 528 for native Thai and 1121 for L2 English. Tukey's HSD post-hoc test indicates that the kurtosis of L2 English [s] is significantly lower than that of native English [s] with a small effect size (*b* = -0.60, *SE* = 0.28, *df* = 81.84, *t* = -2.14, *p* < 0.05, *d* =

0.10) suggesting that native English [s] is more retracted than L2 English [s]. Figure 65 illustrate kurtosis in three language groups.

Table 81. Means and SEs of language, language × gender, language × vowel, language × gender × vowel for the kurtosis of [s] from pairwise comparison based on LMM

		L2 English		Native English		Native Thai	
		Mean	SE	Mean	SE	Mean	SE
Language	Overall	1.34	0.18	1.94	0.25	1.35	0.20
Language × Gender	Male	1.14	0.22	1.74	0.28	1.15	0.24
	Female	1.54	0.21	2.14	0.28	1.55	0.23
Language × Vowel context	High vowel	1.55	0.25	2.15	0.30	1.56	0.27
	Low vowel	1.65	0.21	2.25	0.27	1.66	0.23
	Back vowel	0.82	0.16	1.42	0.25	0.82	0.19
Language × Vowel context × Gender	Male-high	1.35	0.28	1.95	0.33	1.36	0.30
	Male-low	1.45	0.25	2.05	0.30	1.46	0.27
	Male-back	0.62	0.21	1.22	0.28	0.62	0.23
	Female-high	1.75	0.28	2.35	0.33	1.76	0.29
	Female-low	1.85	0.24	2.45	0.30	1.86	0.26
	Female-back	1.02	0.20	1.62	0.28	1.02	0.22

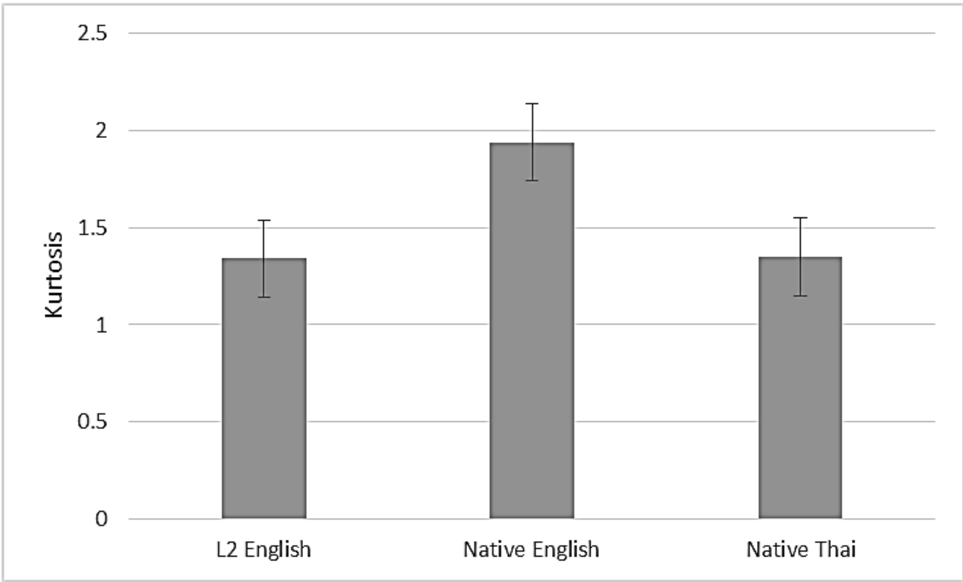

Figure 65. Means of kurtosis for [s] according to language group from pairwise comparison based on LMM

- Normalised amplitude of [s]

Table 82: Mean and SD of noise amplitude and vowel amplitude (in dB, averaged across vowels) in two genders for [s]

Language	Gender	Noise amplitude	Vowel amplitude
L2 English	Female	71.08 (5.63)	75.50 (4.91)
	Male	71.80 (5.04)	77.85 (3.69)
Native English	Female	70.04 (4.97)	72.84 (4.10)
	Male	73.77 (5.60)	78.77 (4.20)
Native Thai	Female	72.71 (5.22)	75.99 (5.31)
	Male	73.34 (3.39)	78.48 (5.84)

In terms of the normalised amplitude of [s], Table 82 shows mean noise amplitude and vowel amplitude for [s] in two genders based on the numbers of stimuli in each language group - 480 for native English, 534 for native Thai and 1119 for L2 English. Table 83 shows the means and SEs in all contexts. Tukey's HSD post-hoc test for the language × gender × vowel interaction indicates that only in the low vowel context in female production is the normalised amplitude of L2 English [s] significantly higher than the normalised amplitude of native Thai [s] with a small effect size (b = 2.06, SE = 0.51, df = 67.57, t = 4.05, p < 0.01, d = 0.17), indicating that in the low vowel context in female production, native Thai [s] is more forward than L2 English [s]. In the same context, the normalised amplitude of native English [s] has tendency to be significantly higher than that of native Thai [s] (p = 0.09). Figure 66 shows that in the low vowel context in female production, the normalised amplitude of L2 English [s] is higher than the normalised amplitude of native Thai [s].

Table 83. Means and SEs of language, language × gender, language × vowel, language × gender × vowel for the normalised amplitude for [s] from pairwise comparison based on LMM

		L2 English		Native English		Native Thai	
		Mean	SE	Mean	SE	Mean	SE
Language	Overall	-5.39	0.43	-3.79	0.66	-5.23	0.45
Language × Gender	Male	-6.33	0.61	-4.85	0.91	-5.01	0.63
	Female	-4.45	0.57	-2.73	0.91	-5.46	0.59
Language × Vowel context	High vowel	-4.96	0.54	-2.91	0.76	-4.75	0.54
	Low vowel	-5.54	0.51	-4.32	0.74	-5.97	0.54
	Back vowel	-5.68	0.48	-4.14	0.70	-4.98	0.52
Language × Vowel context × Gender	Male-high	-6.22	0.72	-3.69	1.03	-4.86	0.74
	Male-low	-6.32	0.70	-5.69	1.01	-5.14	0.74
	Male-back	-6.46	0.66	-5.18	0.95	-5.03	0.70
	Female-high	-3.69	0.67	-2.12	1.03	-4.63	0.70
	Female-low	-4.75	0.65	-2.95	1.01	-6.81	0.71
	Female-back	-4.91	0.62	-3.10	0.95	-4.94	0.67

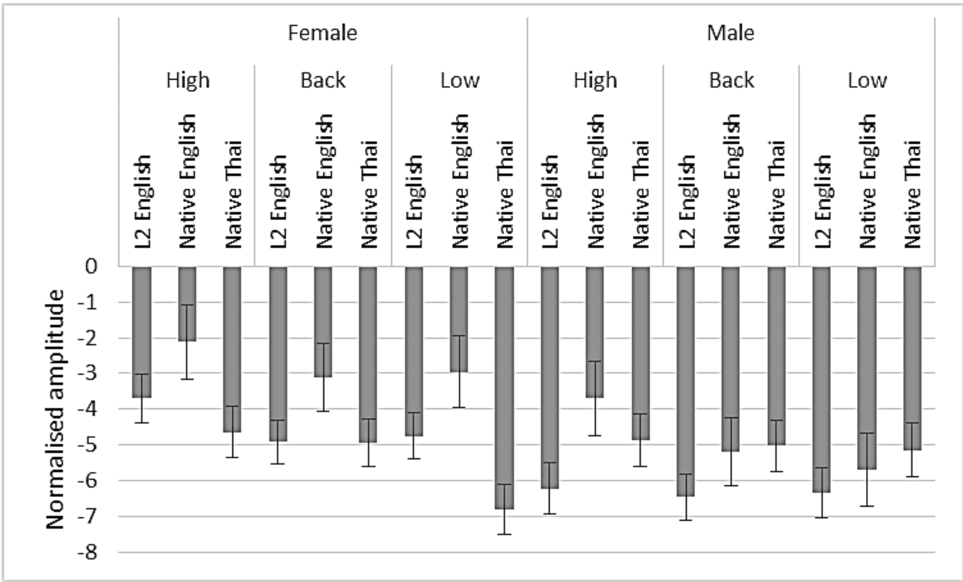

Figure 66. Means of normalised amplitude for [s] according to language group × vowel context × gender from pairwise comparison based on LMM

- Onset F2 frequency of [s]

Table 84 shows the means and SEs for the onset F2 frequency of [s] in all contexts based on the numbers of stimuli in each language group - 476 for native English, 517 for native Thai and 1111 for L2 English. Tukey's HSD post-hoc test for the language × gender interaction indicates that in male production the onset F2 frequency of native English [s] is significantly higher than that of native Thai [s] with a moderate effect size (*b* = 163.53, *SE* = 49.00, *df* = 72.76, *t* = 3.34, *p* < 0.01, *d* = 0.25), suggesting that in male production native Thai [s] is more fronted than native English [s], whereas in female production, the onset F2 frequency of L2 English [s] is significantly higher than the onset F2 frequency of native Thai [s] with a moderate effect size (*b* = 158.63, *SE* = 38.15, *df* = 27.34, *t* = 4.16, *p* < 0.01, *d* = 0.23) and the onset F2 frequency of native English [s] is also significantly higher than that of native Thai [s] with a moderate effect size (*b* = 198.26, *SE* = 48.66, *df* = 71.95, *t* = 4.07, *p* < 0.01, *d* = 0.37), indicating that in female production, native Thai [s] is more fronted than L2 English [s] and native English [s].

Tukey's HSD post-hoc test for the language × vowel interaction indicates that in the back vowel context, the onset F2 frequency of L2 English [s] is significantly lower than the onset F2 frequency of native English [s] with a small effect size (*b*

= -218.51, SE = 30.53, df = 73.53, t = -7.16, $p < 0.01$, d = 0.19). Furthermore, the onset F2 frequency of native English [s] is significantly higher than the onset F2 frequency of native Thai [s] with a moderate effect size (b = 392.47, SE = 68.85, df = 40.67, t = 5.70, $p < 0.01$, d = 0.50), indicating that in the back vowel context, native English [s] is more retracted than L2 English [s] and native Thai [s]. It also shows that in the low vowel, the onset F2 frequency of L2 English [s] is significantly higher than the onset F2 frequency of native English [s] with a small effect size (b = 116.01, SE = 27.12, df = 74.88, t = 4.28, $p < 0.01$, d = 0.10) and that of native Thai [s] with a small effect size (b = 201.68, SE = 62.17, df = 24.33, t = 3.24, $p < 0.05$, d = 0.18), suggesting that in the low vowel context, L2 English [s] is more retracted than native English [s] and native Thai [s].

Figure 67 shows that in male production the onset F2 frequency of native English [s] is significantly higher than that of native Thai [s] and in female production the onset F2 frequency of L2 English [s] and native English [s] are higher than that of native Thai [s]. Figure 68 shows that in the back vowel context, the onset F2 frequency of L2 English [s] and native Thai [s] are lower than the onset F2 frequency of native English [s]. It also shows that in the low vowel context, the onset F2 frequency of L2 English [s] is higher than the onset F2 frequency of native English [s] and native Thai [s].

Table 85 shows the overall interpretation of the acoustic measurements that showed significant differences for L2 English [s]. The SLM prediction that the phonetic properties of L2 English [s] would be different from that of native English [s] is generally confirmed, and more specifically in the overall level in peak location and kurtosis, in female production in centroid, skewness and onset F2 frequency, in male production in centroid and onset F2 frequency and in high vowel context in centroid and skewness, back vowel context in centroid and onset F2 frequency and low vowel context in centroid, skewness and onset F2 frequency, and low vowel context by females in normalised amplitude.

Table 84. Means and SEs of language, language × gender, language × vowel, language × gender × vowel for the onset F2 frequency of [s] from pairwise comparison based on LMM

		L2 English		Native English		Native Thai	
		Mean	SE	Mean	SE	Mean	SE
Language	Overall	1843.55	29.36	1895.82	32.62	1714.92	28.07
Language × Gender	Male	1711.60	31.99	1776.50	37.64	1612.97	31.18
	Female	1975.51	31.31	2015.14	37.64	1816.88	30.67
Language × Vowel context	High vowel	2131.86	55.01	2186.16	57.99	2121.62	46.64
	Low vowel	1802.57	45.56	1686.56	48.86	1600.89	46.42
	Back vowel	1596.23	46.21	1814.74	50.24	1422.27	47.07
Language × Vowel context × Gender	Male-high	1981.70	57.07	2048.63	61.46	2001.45	49.22
	Male-low	1671.56	47.91	1499.88	48.97	1568.19	52.84
	Male-back	1481.54	49.01	1712.68	54.48	1337.57	50.06
	Female-high	2282.03	56.54	2323.70	61.47	2241.78	48.82
	Female-low	1933.57	47.29	1804.93	52.83	1701.89	48.53
	Female-back	1710.92	48.29	1916.80	54.48	1506.96	49.48

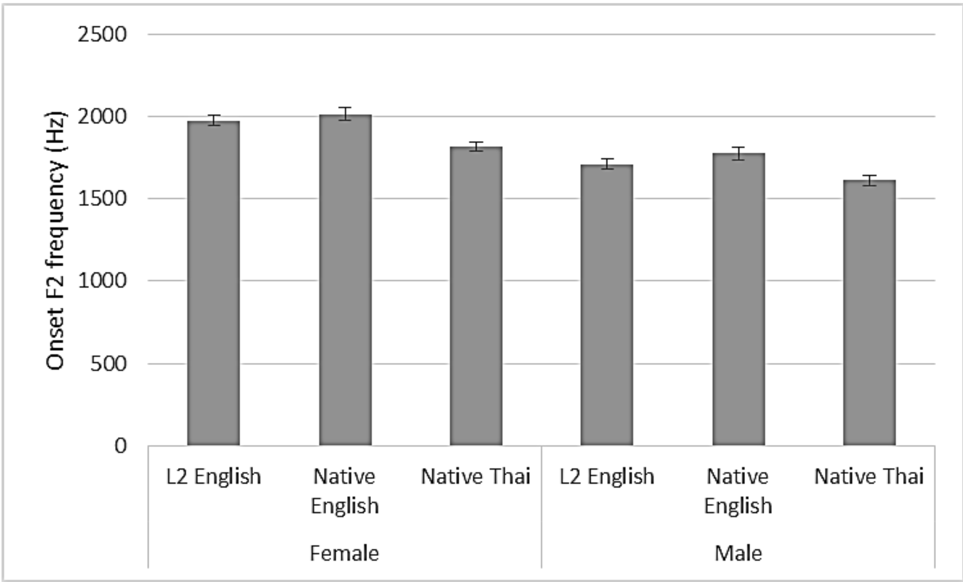

Figure 67. Means of onset F2 frequency for [s] according to language group × gender from pairwise comparison based on LMM

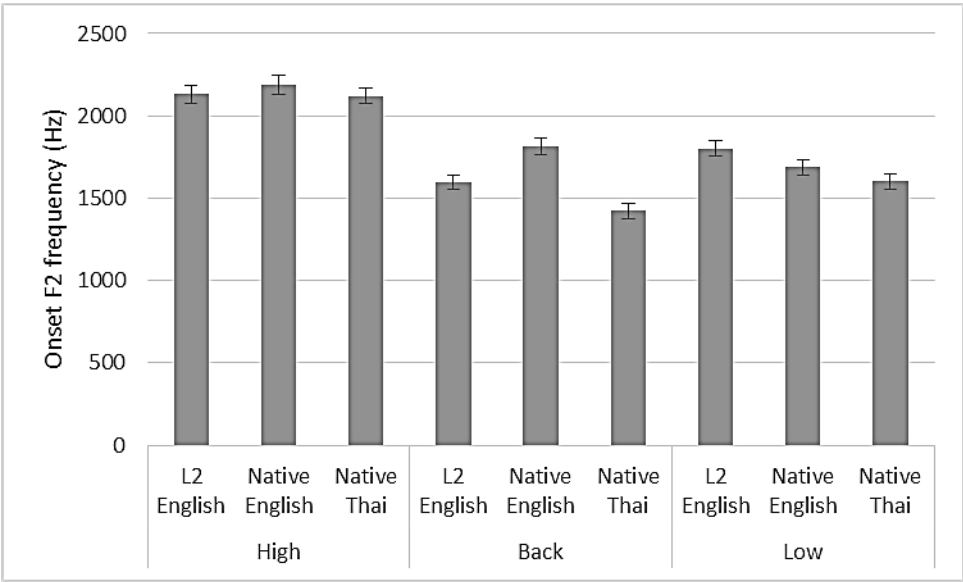

Figure 68. Means of onset F2 frequency for [s] according to language group × vowel context from pairwise comparison based on LMM

Table 85. Interpretation of significant acoustic measurements for L2 English [s]

Position	Measurement	Order	Interpretation	Overall conclusion
Overall	Peak location	T > L2 > E	Native Thai [s] is the most fronted, followed by L2 English [s] and native English [s] respectively	Native Thai [s] is the most fronted, followed by L2 English [s] and native English [s] respectively
	Kurtosis	E > L2	Native English [s] is more retracted than L2 English [s]	
Female	Centroid	T > L2, E	Native Thai [s] is more forward than L2 English [s] and native English [s]	In female production, native Thai [s] is more forward than L2 English [s] and native English [s]
	Skewness	L2 > T	L2 English [s] is more retracted than native Thai [s]	
	F2	L2, E > T	L2 English [s] and native English [s] is more retracted than native Thai [s]	
Male	Centroid	T > L2 > E	Native Thai [s] is the most fronted, followed by L2 English [s] and native English [s], respectively	In male production, native Thai [s] is the most fronted, followed by L2 English [s] and native English [s], respectively
	F2	E > T	Native English [s] is more retracted than native Thai [s]	
High	Centroid	T > L2 > E	Native Thai [s] is the most fronted, followed by L2 English [s] and native English [s], respectively	In high vowel context, native Thai [s] is the most fronted, followed by L2 English [s] and native English [s] respectively
	Skewness	L2 > T	L2 English [s] is more retracted than native Thai [s]	
Low	Centroid	T > L2 > E	Native Thai [s] is the most fronted, followed by L2 English [s] and native English [s], respectively	Three possibilities in low vowel context: 1) native Thai [s] is the most fronted, followed by L2 English [s] and native English [s], respectively; 2) L2 English [s] and native English [s] is more retracted than native Thai [s]; and 3) L2 English [s] is more retracted than native English [s] and native Thai [s]
	Skewness	L2, E > T	L2 English [s] and native English [s] is more retracted than native Thai [s]	
	F2	L2 > E, T	L2 English [s] is more retracted than native English [s] and native Thai [s]	
Back	Centroid	T > L2, E	Native Thai [s] is more fronted than by L2 English [s] and native English [s]	Two possibilities in back vowel context: 1) native Thai [s] is more fronted than by L2 English [s] and native English [s]; 2) native English [s] is more retracted than L2 English [s] and native Thai [s]
	F2	E > L2, T	Native English [s] is more retracted than L2 English [s] and native Thai [s]	
Low by female	Normalised amplitude	L2 > T	L2 English [s] is more retracted than native Thai [s]	In low vowel context by females, L2 English [s] is more retracted than native Thai [s]

6.3.2 Phonetic properties of non-shared fricatives

L2 English [v]

The interpretation of the acoustic measurements of [v] was similar to that of [f] as these two sounds have limited space in terms of the place of articulation. Hence, the interpretation of the acoustic measurements for L2 English [v] is discussed according to the level of effort rather than the place of articulation.

- Peak location (in Hz) of [v]

Table 86 shows the means and SEs in all contexts for the peak location for [v] based on the numbers of stimuli in each language group - 500 for native English and 189 for L2 English. Tukey's HSD post-hoc test indicates no significant difference between the peak location of native English [v] and L2 English [v] in all contexts ($p > 0.05$ for all contrasts).

Table 86. Means and SEs of language, language x gender and language x vowel for the skewness of [v] from pairwise comparison based on LMM

		L2 English		Native English	
		Mean	SE	Mean	SE
Language	Overall	11148.00	355.61	11261.44	300.78
Language × Gender	Male	10080.18	726.26	10800.78	481.22
	Female	10883.03	467.37	11313.98	480.44
Language × Vowel context	High vowel	9482.09	567.36	11057.17	403.06
	Low vowel	10947.41	565.61	11292.79	428.42
	Back vowel	11015.31	484.71	10822.18	337.96
Language × Vowel context × Gender	Male-high	9484.09	848.97	11204.00	559.38
	Male-low	10413.55	854.24	10903.75	588.14
	Male-back	10342.90	781.60	10294.59	486.81
	Female-high	9480.09	606.02	10910.35	561.96
	Female-low	11481.26	596.65	11681.82	597.27
	Female-back	11687.73	512.08	11349.77	470.72

- Centroid (Hz) of [v]

Table 87 shows the means and SEs in all contexts for the centroid of [v] based on the numbers of stimuli in each language group - 534 for native English and 187 for L2 English. Tukey's HSD post-hoc test indicates that there is no significant difference between the centroid of native English [v] and L2 English [v] in all contexts (*p* > 0.05 for all contrasts).

Table 87. Means and SEs of language, language x gender and language x vowel for the centroid of [v] from pairwise comparison based on LMM

		L2 English		Native English	
		Mean	SE	Mean	SE
Language	Overall	9935.761	294.1713	9842.567	254.0346
Language × Gender	Male	9658.947	470.7072	9710.868	350.5143
	Female	10212.58	327.3334	9974.266	351.7802
Language × Vowel context	High vowel	9136.441	412.2845	9964.402	335.5337
	Low vowel	10375.43	385.7714	9670.865	305.8757
	Back vowel	10295.41	297.8106	9892.435	235.0611
Language × Vowel context × Gender	Male-high	9099.781	581.4059	10072.86	449.5362
	Male-low	10005.84	555.8989	9446.394	405.1446
	Male-back	9871.217	472.9424	9613.355	318.8348
	Female-high	9173.102	445.9538	9855.947	451.6601
	Female-low	10745.02	415.0446	9895.336	411.8934
	Female-back	10719.61	328.262	10171.52	318.7711

- SD (in Hz) of [v]

Table 88 shows the means and SEs in all contexts for the SD (in Hz) of [v] based on the numbers of stimuli in each language group - 567 for native English and 202 for L2 English. Tukey's HSD post-hoc test indicates no significant differences between the SD of native English [v] and that of L2 English [v] for all contexts (*p* > 0.05 for all contrasts).

Table 88. Means and SEs of language, language x gender and language x vowel for the SD of [v] from pairwise comparison based on LMM

		L2 English		Native English	
		Mean	SE	Mean	SE
Language	Overall	3322.60	151.68	3507.85	135.95
Language × Gender	Male	3361.59	201.55	3546.83	168.74
	Female	3283.61	159.17	3468.86	168.63
Language × Vowel context	High vowel	3399.07	170.09	3584.32	157.14
	Low vowel	3353.22	179.30	3538.46	167.39
	Back vowel	3215.51	168.01	3400.76	151.74
Language × Vowel context × Gender	Male-high	3438.06	215.47	3623.30	185.92
	Male-low	3392.21	223.19	3577.45	195.08
	Male-back	3254.50	214.28	3439.74	181.90
	Female-high	3360.08	177.14	3545.33	186.45
	Female-low	3314.23	185.56	3499.48	194.74
	Female-back	3176.52	174.59	3361.77	181.40

- Skewness of [v]

Table 89 shows the means and SEs in all contexts for the skewness for /v / based on the numbers of stimuli in each language group - 555 for native English and 190 for L2 English. Tukey's HSD post-hoc test indicates no significant differences between the skewness for native English [v] and L2 English [v] for all contexts (p > 0.05 for all contrasts).

Table 89. Means and SEs of language, language x gender and language x vowel for the skewness of [v] from pairwise comparison based on LMM

		L2 English		Native English	
		Mean	SE	Mean	SE
Language	Overall	-0.52	0.09	-0.54	0.08
Language × Gender	Male	-0.44	0.12	-0.46	0.10
	Female	-0.61	0.10	-0.63	0.10
Language × Vowel context	High vowel	-0.54	0.11	-0.56	0.10
	Low vowel	-0.50	0.10	-0.51	0.09
	Back vowel	-0.54	0.10	-0.56	0.08
Language × Vowel context × Gender	Male-high	-0.45	0.13	-0.47	0.11
	Male-low	-0.41	0.13	-0.43	0.11
	Male-back	-0.45	0.13	-0.47	0.10
	Female-high	-0.62	0.11	-0.64	0.12
	Female-low	-0.58	0.11	-0.60	0.11
	Female-back	-0.62	0.10	-0.64	0.10

- Kurtosis of [v]

In relation to kurtosis of [v], Table 90 shows the means and SEs in all contexts based on the numbers of stimuli in each language group - 554 for native English and 197 for L2 English. Tukey's HSD post-hoc test indicates no significant differences between the kurtosis for native English [v] and L2 English [v] for all contexts ($p > 0.05$ for all contrasts).

Table 90. Means and SEs of language, language x gender and language x vowel for the kurtosis of [v] from pairwise comparison based on LMM

		L2 English		Native English	
		Mean	SE	Mean	SE
Language	Overall	0.91	0.28	0.80	0.22
Language × Gender	Male	0.64	0.37	0.53	0.28
	Female	1.19	0.29	1.07	0.28
Language × Vowel context	High vowel	0.81	0.31	0.69	0.25
	Low vowel	0.87	0.32	0.76	0.27
	Back vowel	1.06	0.30	0.95	0.25
Language × Vowel context × Gender	Male-high	0.54	0.39	0.42	0.30
	Male-low	0.60	0.40	0.48	0.32
	Male-back	0.79	0.39	0.67	0.31
	Female-high	1.08	0.32	0.96	0.31
	Female-low	1.15	0.33	1.03	0.32
	Female-back	1.33	0.32	1.22	0.31

- Normalised amplitude of [v]

Table 91: Mean and SD of noise amplitude and vowel amplitude (in dB, averaged across vowels) in two genders for [v]

Language	Gender	Noise amplitude	Vowel amplitude
L2 English	Female	70.30 (3.89)	77.13 (3.89)
	Male	73.54 (3.12)	79.73 (3.48)
Native English	Female	67.29 (3.83)	73.98 (4.16)
	Male	72.33 (4.81)	79.93 (4.04)

For normalised amplitude for [v], Table 91 shows mean noise amplitude and vowel amplitude in two genders for [v] and Table 92 shows the means and SDs in all contexts based on the numbers of stimuli in each language group - 580 for native English and 205 for L2 English. Tukey's HSD post-hoc test indicates no significant difference between normalised amplitude for native English [v] and that for L2 English [v] in all contexts ($p > 0.05$ for all contrasts).

Table 92. Means and SEs of language, language x gender and language x vowel for the normalised amplitude of [v] from pairwise comparison based on LMM

		L2 English		Native English	
		Mean	SE	Mean	SE
Language	Overall	-6.79	0.33	-6.97	0.26
Language × Gender	Male	-6.48	0.52	-7.38	0.34
	Female	-7.10	0.36	-6.57	0.35
Language × Vowel context	High vowel	-6.28	0.42	-7.04	0.32
	Low vowel	-6.67	0.48	-6.36	0.37
	Back vowel	-7.43	0.43	-7.52	0.34
Language × Vowel context × Gender	Male-high	-5.98	0.59	-7.45	0.40
	Male-low	-6.21	0.66	-6.62	0.46
	Male-back	-7.26	0.61	-8.07	0.43
	Female-high	-6.57	0.46	-6.62	0.40
	Female-low	-7.12	0.50	-6.11	0.47
	Female-back	-7.61	0.46	-6.98	0.43

- Onset F2 frequency of [v]

Table 93 shows the means and SEs of onset F2 frequency for [v] in all contexts based on the numbers of stimuli in each language group - 580 for native English and 200 for L2 English. Tukey's HSD post-hoc test indicates that in the low vowel context, the onset F2 frequency of native English [v] is significantly lower than that of L2 English [v] with a small effect size (b = -132.62, SE = 43.47, df = 45.51, t = -3.05, $p < 0.05$, d = 0.19), indicating that in the low vowel context, L2 English [v] is produced with more effort than native English [v]. Figure 69 shows the onset F2 frequency of the two language groups in the three vowel contexts.

Table 93. Means and SEs of language, language x gender and language x vowel for the onset F2 frequency of [v] from pairwise comparison based on LMM

		L2 English		Native English	
		Mean	SE	Mean	SE
Language	Overall	1577.95	38.59	1565.48	35.94
Language × Gender	Male	1505.91	49.70	1483.83	41.32
	Female	1649.99	40.72	1647.13	41.42
Language × Vowel context	High vowel	1987.04	67.19	2032.20	60.91
	Low vowel	1623.57	64.71	1490.95	61.13
	Back vowel	1123.25	54.29	1173.29	51.55
Language × Vowel context × Gender	Male-high	1872.43	80.64	1907.98	69.07
	Male-low	1532.93	74.74	1390.70	65.72
	Male-back	1112.37	62.37	1152.80	55.12
	Female-high	2101.65	69.92	2156.42	69.11
	Female-low	1714.20	65.56	1591.20	66.09
	Female-back	1134.13	56.27	1193.78	55.15

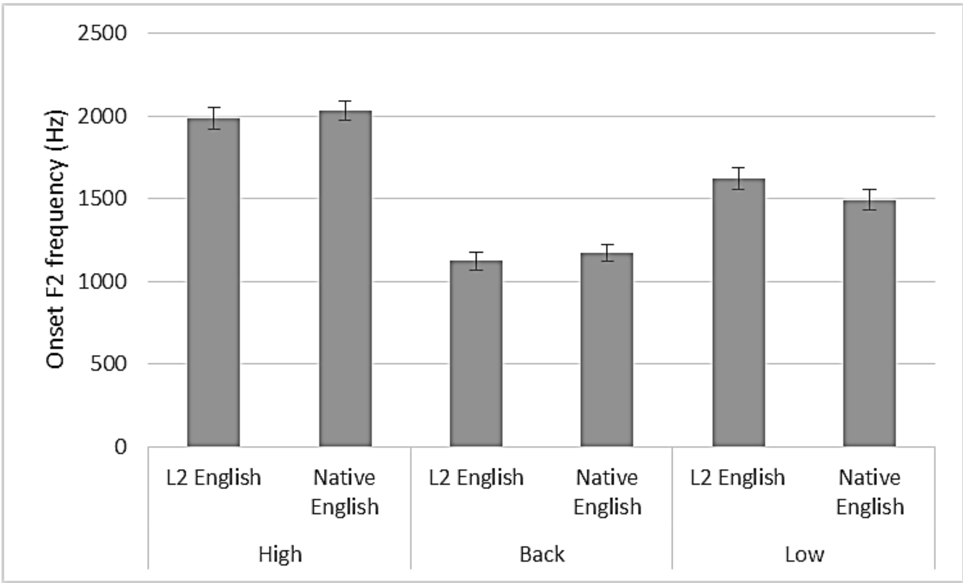

Figure 69. Means of the onset F2 frequency for [v] according to language group × vowel context from pairwise comparison based on LMM

Table 94 shows a summary of the interpretations of the acoustic measurements for L2 English [v]. The results shows no significant difference in the acoustic characteristics for most contexts, except the low vowel context in onset F2 frequency.

Table 94. Interpretation of the significant acoustic measurements for L2 English [v]

Position	Measurement	Order	Interpretation	Overall conclusion
Low	F2	L2 > E	L2 English [v] involves higher effort than native English [v]	In low vowel context, L2 English [v] involves higher effort than native English [v]

L2 English [θ]

- Peak location (in Hz) of [θ]

Table 95 shows the means and SEs for the peak location for [θ], in all contexts based on the numbers of stimuli in each language group - 390 for native English and 288 for L2 English. Tukey's HSD post-hoc test indicates no significant difference between the peak location of native English [θ] and that of L2 English [θ] for all contexts (p > 0.05 for all contrasts).

Table 95. Means and SEs of language, language x gender and language x vowel for the peak location of [θ] from pairwise comparison based on LMM

		L2 English		Native English	
		Mean	SE	Mean	SE
Language	Overall	10499.36	355.35	10248.76	373.36
Language × Gender	Male	9544.58	525.16	10399.08	506.00
	Female	11454.15	442.14	10098.44	510.37
Language × Vowel context	High vowel	10659.21	425.06	10262.38	430.07
	Low vowel	11123.77	560.65	10360.98	575.85
	Back vowel	9715.12	383.69	10122.91	355.86
Language × Vowel context × Gender	Male-high	9549.03	595.98	10257.31	566.14
	Male-low	10341.38	738.70	10683.71	717.05
	Male-back	8743.31	551.61	10256.21	481.28
	Female-high	11769.38	512.16	10267.45	573.50
	Female-low	11906.15	650.07	10038.26	733.45
	Female-back	10686.93	467.20	9989.61	483.75

- Centroid (in Hz) of [θ]

Table 96 shows the means and SEs for the centroid (in Hz) for [θ] in all contexts based on the numbers of stimuli in each language group - 389 for native English and 300 for L2 English. Tukey's HSD post-hoc test for the language × gender interaction indicates that in female production, the centroid of native English [θ] is significantly lower than that of L2 English [θ] with a moderate effect size (b = -1354.33, SE = 398.41, df = 51.95, t = -3.40, p < 0.01, d = 0.36), but there is no significant difference between the peak location of L2 English [θ] and that of L2 English [θ] in all vowel contexts (p > 0.05 for all contrasts). This suggests that in female production, L2 English [θ] is more fronted than native English [θ]. Figure 70 shows the centroid of the two language groups in the two genders.

Table 96. Means and SEs of language, language x gender and language x vowel for the centroid of [θ] from pairwise comparison based on LMM

		L2 English		Native English	
		Mean	SE	Mean	SE
Language	Overall	10482.61	192.72	10029.07	216.16
Language × Gender	Male	9735.75	289.45	10183.00	305.55
	Female	11229.47	253.29	9875.15	307.43
Language × Vowel context	High vowel	10520.20	219.31	9956.97	237.53
	Low vowel	10617.30	253.30	10105.18	268.12
	Back vowel	10310.34	211.94	10025.07	226.38
Language × Vowel context × Gender	Male-high	9776.65	318.06	10114.21	328.76
	Male-low	9848.87	354.87	10237.53	356.21
	Male-back	9581.75	304.21	10197.26	316.53
	Female-high	11263.75	277.86	9799.74	330.66
	Female-low	11385.73	310.90	9972.82	364.22
	Female-back	11038.94	277.82	9852.88	317.14

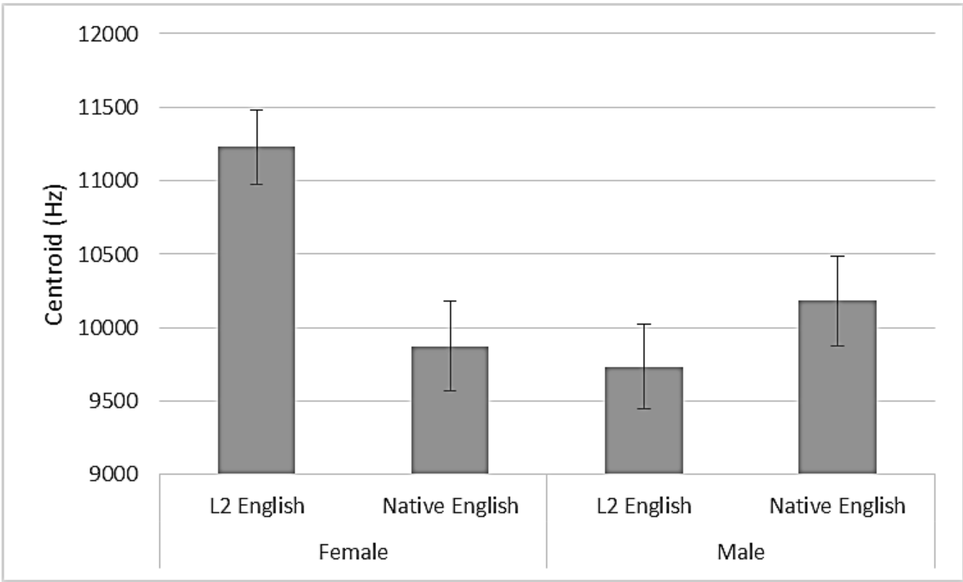

Figure 70. Means of the centroid (Hz) of [θ] according to language group × gender from pairwise comparison based on LMM

- SD (in Hz) of [θ]

Table 97 shows the means and SEs for the SD (in Hz) of [θ] in all contexts based on the numbers of stimuli in each language group - 381 for native English and 289 for L2 English. Tukey's HSD post-hoc test for the language × gender interaction indicates that in female production, the SD of native English [θ] is significantly higher than that of L2 English [θ] with a moderate effect size (b = 362.64, SE = 96.19, df = 50.55, t = 3.77, p < 0.01, d = 0.41), whereas Tukey's HSD post-hoc test for the language × vowel interaction shows that in the high vowel context, the SD of native English [θ] is also significantly higher than the SD of L2 English [θ] with a moderate effect size (b = 263.89, SE = 82.11, df = 45.57, t = 3.21, $p < 0.05$, d = 0.38). This suggests that in female production and in the high vowel context, L2 English [θ] is more retracted than native English [θ]. Figure 71 and Figure 72 show the SD of the two language groups in the two genders and the three vowel contexts, respectively.

Table 97. Means and SEs of language, language x gender and language x vowel for the SD of [θ] from pairwise comparison based on LMM

		L2 English		Native English	
		Mean	SE	Mean	SE
Language	Overall	2808.49	48.08	2956.08	48.69
Language × Gender	Male	2927.48	72.91	2860.01	68.85
	Female	2689.51	63.98	3052.14	70.60
Language × Vowel context	High vowel	2825.20	59.31	3089.09	56.91
	Low vowel	2905.38	80.20	2965.71	79.07
	Back vowel	2694.90	64.32	2813.44	62.28
Language × Vowel context × Gender	Male-high	2909.78	84.73	2958.62	77.88
	Male-low	3028.07	109.98	2873.35	100.64
	Male-back	2844.57	88.98	2748.06	84.93
	Female-high	2740.62	75.22	3219.56	79.90
	Female-low	2782.68	97.80	3058.06	106.64
	Female-back	2545.22	82.36	2878.82	84.80

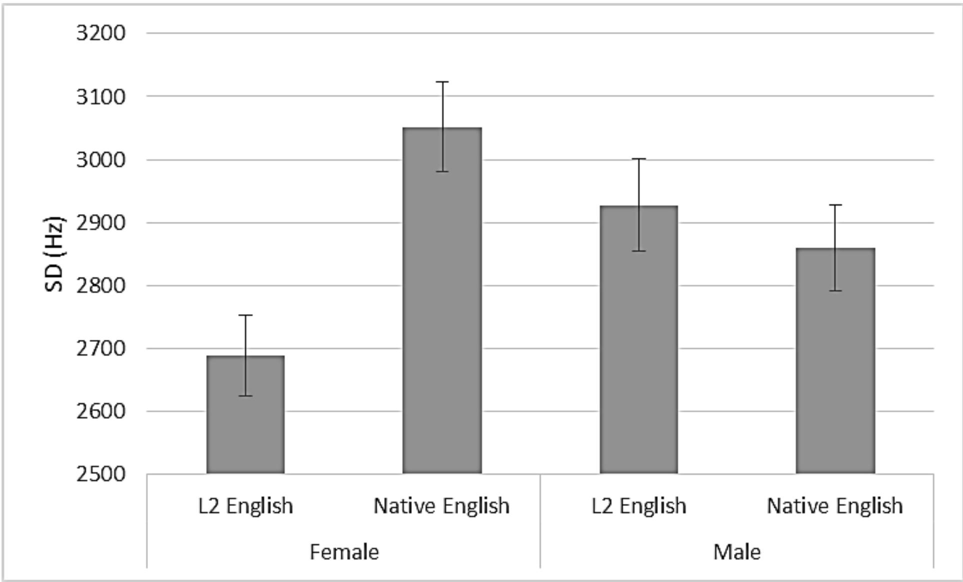

Figure 71. Means of the centroid (Hz) of [θ] according to language group × gender from pairwise comparison based on LMM

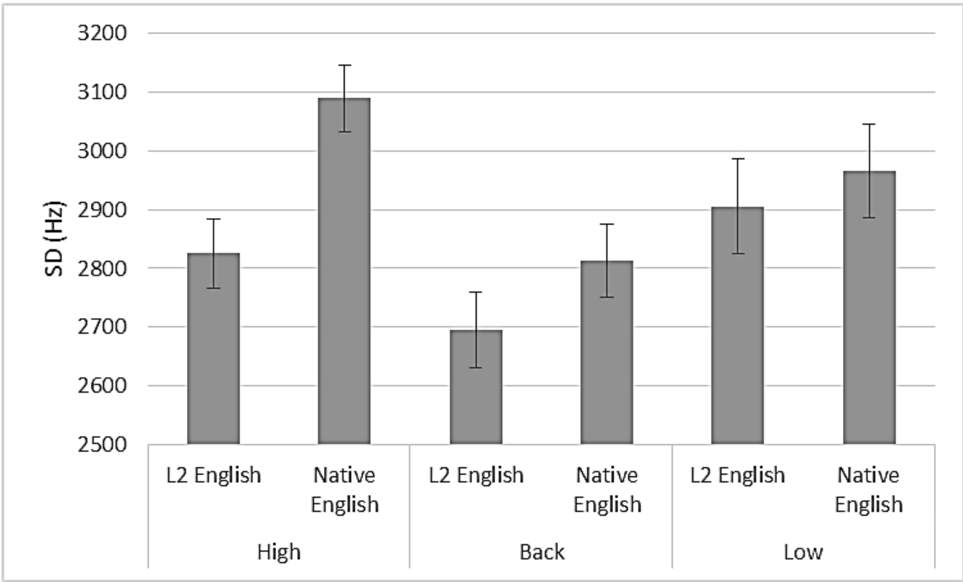

Figure 72. Means of the centroid (Hz) of [θ] according to language group × vowel from pairwise comparison based on LMM

- Skewness of [θ]

Table 98 shows the means and SEs for the skewness of [θ] in all contexts based on the numbers of stimuli in each language group - 383 for native English and 300 for L2 English. Tukey's HSD post-hoc test indicates no significant difference between the skewness of L2 English [θ] and that of native English [θ] for all contexts (p > 0.05 for all contrasts).

Table 98. Means and SEs of language, language x gender and language x vowel for the skewness of [θ] from pairwise comparison based on LMM

		L2 English		Native English	
		Mean	SE	Mean	SE
Language	Overall	-0.22	0.07	-0.25	0.08
Language × Gender	Male	0.02	0.11	-0.28	0.11
	Female	-0.47	0.09	-0.23	0.11
Language × Vowel context	High vowel	-0.21	0.08	-0.25	0.08
	Low vowel	-0.31	0.10	-0.37	0.10
	Back vowel	-0.15	0.08	-0.14	0.08
Language × Vowel context × Gender	Male-high	0.12	0.12	-0.29	0.11
	Male-low	-0.06	0.15	-0.45	0.14
	Male-back	0.00	0.12	-0.10	0.12
	Female-high	-0.54	0.10	-0.20	0.12
	Female-low	-0.56	0.13	-0.29	0.15
	Female-back	-0.30	0.11	-0.19	0.12

- Kurtosis of [θ]

Table 99 shows the means and SEs for the kurtosis for [θ] in all contexts based on the numbers of stimuli in each language group - 375 for native English and 294 for L2 English. Tukey's HSD post-hoc test indicates no significant difference between the kurtosis of L2 English [θ] and native English [θ] for all contexts ($p >$ 0.05 for all contrasts) even though the kurtosis of native English [θ] has tendency to be significantly lower than that of L2 English [θ] (p = 0.08).

Table 99. Means and SEs of language, language x gender and language x vowel for the kurtosis of [θ] from pairwise comparison based on LMM

		L2 English		Native English	
		Mean	SE	Mean	SE
Language	Overall	1.22	0.53	0.83	0.54
Language × Gender	Male	1.22	0.55	0.84	0.55
	Female	1.21	0.54	0.83	0.55
Language × Vowel context	High vowel	0.67	0.21	0.28	0.21
	Low vowel	2.11	1.38	1.73	1.40
	Back vowel	0.87	0.23	0.49	0.22
Language × Vowel context × Gender	Male-high	0.67	0.26	0.29	0.25
	Male-low	2.12	1.39	1.74	1.40
	Male-back	0.88	0.27	0.49	0.26
	Female-high	0.66	0.24	0.28	0.25
	Female-low	2.11	1.39	1.72	1.40
	Female-back	0.86	0.25	0.48	0.26

- Normalised amplitude of [θ]

Table 100: Mean and SD of noise amplitude and vowel amplitude (in dB, averaged across vowels) in two genders for [θ]

Language	Gender	Noise amplitude	Vowel amplitude
L2 English	Female	68.33 (4.82)	76.46 (4.54)
	Male	70.46 (3.91)	76.82 (4.03)
Native English	Female	66.36 (4.43)	73.62 (4.25)
	Male	70.32 (5.49)	79.43 (4.75)

Table 100 shows mean noise amplitude and vowel amplitude in two genders for [θ] based on the numbers of stimuli in each language group - 391 for native English and 312 for L2 English. Table 101 shows the means and SEs for the normalised amplitude of [θ] in all contexts. Tukey's HSD post-hoc test for the language × gender interaction indicates that in male production, the normalised amplitude of native English [θ] is significantly lower than that of L2 English [θ] with a moderate effect size (b = -2.42, SE = 0.48, df = 50.85, t = -5.03, p < 0.01, d = 0.53) and in female production, the normalised amplitude of native English [θ] is significantly higher than that of L2 English [θ] with a small to moderate effect size

(b = 1.08, SE = 0.46, df = 51.15, t = 2.37, p < 0.05, d = 0.24). However, no significant difference is found between the normalised amplitude for L2 English [θ] and that of native English [θ] in all vowel contexts (p > 0.05 for all contrasts) although the normalised amplitude of native English [θ] has tendency to be significantly lower than that of L2 English [θ] (p = 0.08). This suggests that in male production, L2 English [θ] is produced with higher effort than native English [θ] which is contrastive to what was found for female production. Figure 73 shows the normalised amplitude of the two language groups in the two genders.

Table 101. Means and SEs of language, language x gender and language x vowel for the normalised amplitude of [θ] from pairwise comparison based on LMM

		L2 English		Native English	
		Mean	SE	Mean	SE
Language	Overall	-7.13	0.24	-7.80	0.25
Language × Gender	Male	-6.39	0.35	-8.81	0.34
	Female	-7.88	0.32	-6.79	0.35
Language × Vowel context	High vowel	-7.32	0.31	-8.21	0.30
	Low vowel	-6.82	0.42	-6.87	0.41
	Back vowel	-7.26	0.33	-8.32	0.32
Language × Vowel context × Gender	Male-high	-6.16	0.42	-8.81	0.39
	Male-low	-6.33	0.55	-8.14	0.51
	Male-back	-6.67	0.44	-9.48	0.42
	Female-high	-8.48	0.38	-7.62	0.40
	Female-low	-7.30	0.50	-5.60	0.53
	Female-back	-7.85	0.41	-7.16	0.42

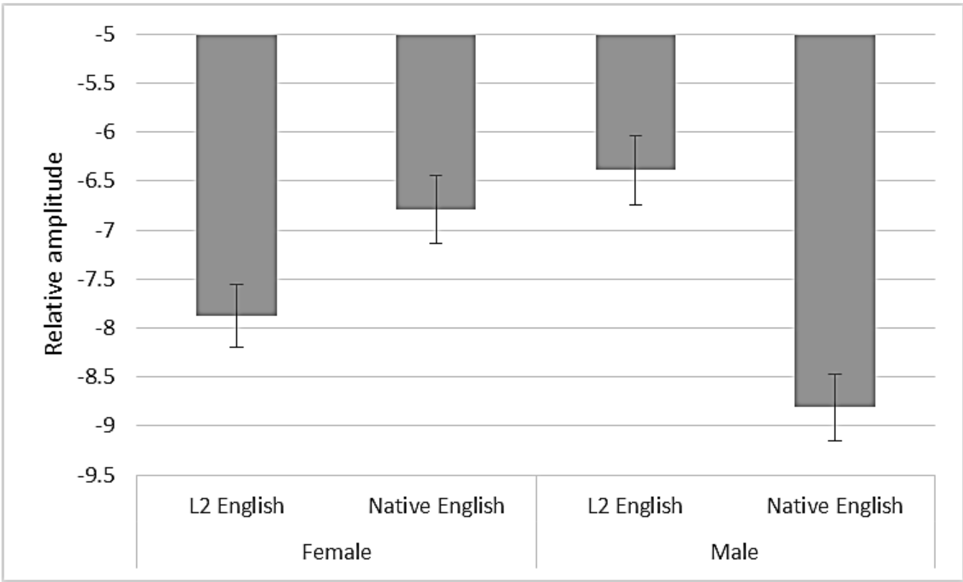

Figure 73. Means of the normalised amplitude for [θ] according to language group × gender from pairwise comparison based on LMM

- Onset F2 frequency of [θ]

Table 102 shows the means and SEs of onset F2 frequency for [θ] in all contexts based on the numbers of stimuli in each language group - 389 for native English and 309 for L2 English. Tukey's HSD post-hoc tests indicate no significant difference between the onset F2 frequency of native English [θ] and that of L2 English [θ] for all contexts (p > 0.05 for all contrasts). Tukey's HSD post-hoc test for language × vowel interaction indicates tendency of the onset F2 frequency of native English [θ] to be significantly lower than that of L2 English [θ] (p = 0.09).

Table 102. Means and SEs of language, language x gender and language x vowel for the onset F2 frequency of [θ] from pairwise comparison based on LMM

		L2 English		Native English	
		Mean	SE	Mean	SE
Language	Overall	1709.41	37.87	1671.09	39.33
Language × Gender	Male	1585.14	44.81	1553.02	46.23
	Female	1833.68	42.48	1789.16	46.40
Language × Vowel context	High vowel	1980.19	50.51	2044.10	51.59
	Low vowel	1717.12	77.76	1644.64	78.27
	Back vowel	1430.93	51.49	1324.53	53.00
Language × Vowel context × Gender	Male-high	1812.64	57.46	1882.74	58.43
	Male-low	1592.08	82.66	1525.80	82.64
	Male-back	1350.72	59.06	1250.51	60.32
	Female-high	2147.75	55.50	2205.46	58.61
	Female-low	1842.15	80.64	1763.47	83.11
	Female-back	1511.15	56.64	1398.55	60.34

Table 103 shows the interpretations of the acoustic measurements for L2 English [θ]. The results show no acoustic differences in all contexts, except female production in centroid, SD and normalised amplitude, male production in normalised amplitude and the high vowel context in SD.

Table 103. Interpretation of significant acoustic measurements for L2 English [θ]

Position	Measurement	Order	Interpretation	Overall conclusion
Female	Centroid	L2 > E	L2 English [θ] is more fronted than native English [θ]	Three possibilities in female production: 1) L2 English [θ] is more fronted than native English [θ]; 2) L2 English [θ] is more retracted than native English [θ]; and 3) native English [θ] is involves higher effort than L2 English [θ]
	SD	E > L2	L2 English [θ] is more retracted than native English [θ]	
	Normalised amplitude	E > L2	Native English [θ] is involves higher effort than L2 English [θ]	
Male	Normalised amplitude	L2 > E	L2 English [θ] involves higher effort than native English [θ]	In male production, L2 English [θ] involves higher effort than native English [θ]
High	SD	E > L2	L2 English [θ] is more retracted than native English [θ]	In high vowel context, L2 English [θ] is more retracted effort than native English [θ]

L2 English [ð]

- Peak location (in Hz) of [ð]

Table 104 shows the means and SEs of the peak location of [ð] in all contexts based on the numbers of stimuli in each language group - 130 for native English and 38 for L2 English. Tukey's HSD post-hoc test indicates no significant difference between the peak location of native English [ð] and that of L2 English [ð] for all contexts (*p* > 0.05 for all contrasts).

Table 104. Means and SEs of language, language x gender and language x vowel for the peak location of [ð] from pairwise comparison based on LMM

		L2 English		Native English	
		Mean	SE	Mean	SE
Language	Overall	7339.72	1012.62	8404.64	659.90
Language × Gender	Male	6217.16	1252.01	8160.48	895.34
	Female	8462.28	1596.89	8648.81	961.03
Language × Vowel context	High vowel	8033.19	1384.14	7899.26	804.64
	Low vowel	6646.26	1065.29	8910.03	744.66
Language × Vowel context × Gender	Male-high	6088.99	1554.26	8307.91	1121.42
	Male-low	6345.33	1432.28	8013.05	938.23
	Female-high	9977.38	2314.21	7490.61	1143.11
	Female-low	6947.19	1565.87	9807.01	1138.57

- Centroid (in Hz) of [ð]

Table 105 shows the means and SEs of the centroid (in Hz) for [ð] in all contexts based on the numbers of stimuli in each language group - 139 for native English and 38 for L2 English. Tukey's HSD post-hoc test indicates no significant difference between the centroid of native English [ð] and that of L2 English [ð] for all contexts (*p* > 0.05 for all contrasts).

Table 105. Means and SEs of language, language x gender and language x vowel for the centroid of [ð] from pairwise comparison based on LMM

		L2 English		Native English	
		Mean	SE	Mean	SE
Language	Overall	7423.72	688.03	8117.92	481.81
Language × Gender	Male	7043.00	770.21	7737.19	605.84
	Female	7804.45	809.01	8498.65	631.02
Language × Vowel context	High vowel	7045.07	749.56	7739.27	574.75
	Low vowel	7802.37	680.93	8496.57	461.15
Language × Vowel context × Gender	Male-high	6664.35	826.71	7358.54	683.39
	Male-low	7421.64	762.71	8115.84	588.03
	Female-high	7425.80	860.91	8120.00	703.28
	Female-low	8183.10	804.09	8877.30	616.83

- SD (in Hz) of [ð]

Table 106 shows the means and SEs of the SD (in Hz) for [ð] in all contexts based on the numbers of stimuli in each language group - 139 for native English and 38 for L2 English. Tukey's HSD post-hoc test indicates no significant difference between the SD of native English [ð] and that of L2 English [ð] for all contexts ($p > 0.05$ for all contrasts).

Table 106. Means and SEs of language, language x gender and language x vowel for the SD of [ð] from pairwise comparison based on LMM

		L2 English		Native English	
		Mean	SE	Mean	SE
Language	Overall	3626.21	144.12	3572.72	81.41
Language × Gender	Male	3485.16	152.25	3431.67	106.24
	Female	3767.26	170.57	3713.77	112.70
Language × Vowel context	High vowel	3645.10	161.59	3591.61	105.31
	Low vowel	3607.32	157.76	3553.83	107.82
Language × Vowel context × Gender	Male-high	3504.06	168.07	3450.56	124.39
	Male-low	3466.27	166.06	3412.78	128.69
	Female-high	3786.15	186.31	3732.66	132.06
	Female-low	3748.37	181.49	3694.87	131.99

- Skewness of [ð]

Table 107 shows the means and SEs of the skewness for [ð] in all contexts based on the numbers of stimuli in each language group - 126 for native English and 37 for L2 English. Tukey's HSD post-hoc test indicates no significant difference between the skewness of native English [ð] and that of L2 English [ð] for all contexts ($p > 0.05$ for all contrasts) although the skewness of native English [ð] has tendency to be significantly lower than that of L2 English [ð] ($p = 0.09$).

Table 107. Means and SEs of language, language x gender and language x vowel for the skewness of [ð] from pairwise comparison based on LMM

		L2 English		Native English	
		Mean	SE	Mean	SE
Language	Overall	0.119409	0.21	-0.21976	0.14
Language × Gender	Male	0.22	0.23	-0.12	0.18
	Female	0.02	0.25	-0.32	0.18
Language × Vowel context	High vowel	0.15	0.22	-0.19	0.16
	Low vowel	0.09	0.21	-0.25	0.14
Language × Vowel context × Gender	Male-high	0.25	0.24	-0.09	0.19
	Male-low	0.19	0.23	-0.15	0.18
	Female-high	0.05	0.26	-0.29	0.20
	Female-low	-0.01	0.25	-0.35	0.19

- Kurtosis of [ð]

Table 108 shows the means and SEs of the kurtosis for [ð] in all contexts based on the numbers of stimuli in each language group - 133 for native English and 34 for L2 English. Tukey's HSD post-hoc test indicates no significant difference between the kurtosis of native English [ð] and that of L2 English [ð] for all contexts ($p > 0.05$ for all contrasts).

Table 108. Means and SEs of language, language x gender and language x vowel for the kurtosis of [ð] from pairwise comparison based on LMM

		L2 English		Native English	
		Mean	SE	Mean	SE
Language	Overall	0.86	0.56	0.74	0.32
Language × Gender	Male	1.08	0.59	0.96	0.42
	Female	0.64	0.67	0.52	0.44
Language × Vowel context	High vowel	0.85	0.60	0.74	0.35
	Low vowel	0.87	0.62	0.75	0.44
Language × Vowel context × Gender	Male-high	1.07	0.62	0.96	0.44
	Male-low	1.09	0.65	0.97	0.52
	Female-high	0.63	0.70	0.52	0.47
	Female-low	0.65	0.71	0.53	0.53

- Normalised amplitude of [ð]

Table 109: Mean and SD of noise amplitude and vowel amplitude (in dB, averaged across vowels) in two genders for [ð]

Language	Gender	Noise amplitude	Vowel amplitude
L2 English	Female	70.90 (5.42)	76.54 (3.84)
	Male	72.32 (3.26)	79.07 (3.93)
Native English	Female	67.62 (4.11)	74.00 (4.17)
	Male	72.15 (4.65)	79.03 (3.43)

Table 109 shows mean noise amplitude and vowel amplitude in two genders for [ð] and Table 110 shows the means and SEs of the normalised amplitude for [ð] in all contexts based on the numbers of stimuli in each language group - 180 for native English and 44 for L2 English. Tukey's HSD post-hoc test indicates no significant difference between the normalised amplitude of L2 English [ð] and that of native English [ð] for all contexts (p > 0.05 for all contrasts).

Table 110. Means and SEs of language, language x gender and language x vowel for the normalised amplitude of [ð] from pairwise comparison based on LMM

		L2 English		Native English	
		Mean	SE	Mean	SE
Language	Overall	-6.17	0.42	-6.48	0.26
Language × Gender	Male	-6.45	0.45	-6.75	0.33
	Female	-5.90	0.49	-6.21	0.35
Language × Vowel context	High vowel	-6.54	0.43	-6.85	0.27
	Low vowel	-5.81	0.46	-6.12	0.34
Language × Vowel context × Gender	Male-high	-6.81	0.46	-7.12	0.34
	Male-low	-6.08	0.50	-6.39	0.40
	Female-high	-6.26	0.50	-6.57	0.36
	Female-low	-5.54	0.53	-5.84	0.41

- Onset F2 frequency of [ð]

Table 111 shows the means and SEs of the onset F2 frequency for [ð] in all contexts based on the numbers of stimuli in each language group - 181 for native English and 42 for L2 English. Tukey's HSD post-hoc test indicates no significant difference between of the onset F2 frequency of L2 English [ð] and that of native English [ð] for all contexts (p > 0.05 for all contrasts).

Table 111. Means and SEs of language, language x gender and language x vowel for the onset F2 frequency of [ð] from pairwise comparison based on LMM

		L2 English		Native English	
		Mean	SE	Mean	SE
Language	Overall	1984.63	67.38	1879.01	62.42
Language × Gender	Male	1895.41	74.41	1737.04	67.39
	Female	2073.85	78.83	2020.99	68.08
Language × Vowel context	High vowel	2086.15	89.31	2043.31	84.19
	Low vowel	1883.11	91.02	1714.71	85.65
Language × Vowel context × Gender	Male-high	2023.74	95.35	1871.21	87.92
	Male-low	1767.08	99.68	1602.86	90.22
	Female-high	2148.56	100.05	2215.41	88.34
	Female-low	1999.13	101.84	1826.56	91.58

In the production of L2 English [ð], no acoustic differences were found in all contexts.

L2 English [z]

- Peak location (in Hz) of [z]

Table 112 shows the means and SEs of the peak location (in Hz) for [z] in all contexts based on the numbers of stimuli in each language group - 376 for native English and 196 for L2 English. Tukey's HSD post-hoc test indicates no significant difference between the peak location of native English [z] and that of L2 English [z] for all contexts (p > 0.05 for all contrasts) even though the peak location of native English [z] has tendency to be significantly lower than that of L2 English [z] (p = 0.09).

Table 112. Means and SEs of language, language x gender and language x vowel for the peak location of [z] from pairwise comparison based on LMM

		L2 English		Native English	
		Mean	SE	Mean	SE
Language	Overall	8088.20	277.44	7581.24	254.31
Language × Gender	Male	7187.16	353.54	6680.20	315.05
	Female	8989.24	312.34	8482.28	314.16
Language × Vowel context	High vowel	8257.19	277.94	7750.24	254.68
	Low vowel	8291.35	331.79	7784.40	312.40
	Back vowel	7716.04	300.33	7209.09	279.62
Language × Vowel context × Gender	Male-high	7356.15	353.21	6849.20	314.54
	Male-low	7390.31	397.50	6883.36	363.44
	Male-back	6815.00	372.58	6308.04	336.70
	Female-high	9158.24	313.60	8651.28	315.27
	Female-low	9192.40	361.60	8685.44	362.91
	Female-back	8617.08	331.93	8110.13	334.07

- Centroid (in Hz) of [z]

Table 113 shows the means and SEs of the centroid (in Hz) for [z] in all contexts based on the numbers of stimuli in each language group - 378 for native English and 197 for L2 English. Tukey's HSD post-hoc test indicates that the centroid of native English [z] is significantly lower than that of L2 English [z] with a small effect size (b = -576.60, SE = 282.21, df = 44.60, t = -2.04, p < 0.05, d = 0.16), suggesting that L2 English [z] is more fronted than native English [z]. Figure 74 shows the centroid of the two language groups across contexts.

Table 113. Means and SEs of language, language x gender and language x vowel for the centroid of [z] from pairwise comparison based on LMM

		L2 English		Native English	
		Mean	SE	Mean	SE
Language	Overall	8618.53	205.67	8041.92	200.35
Language × Gender	Male	7870.64	264.55	7294.04	246.72
	Female	9366.41	235.19	8789.81	245.18
Language × Vowel context	High vowel	8758.99	210.80	8182.38	207.09
	Low vowel	8747.80	245.58	8171.19	238.78
	Back vowel	8348.79	216.25	7772.19	212.44
Language × Vowel context × Gender	Male-high	8011.11	268.19	7434.50	251.82
	Male-low	7999.92	296.56	7423.31	278.74
	Male-back	7600.91	273.32	7024.31	257.12
	Female-high	9506.87	240.11	8930.27	251.11
	Female-low	9495.68	270.88	8919.08	277.56
	Female-back	9096.68	243.99	8520.07	254.66

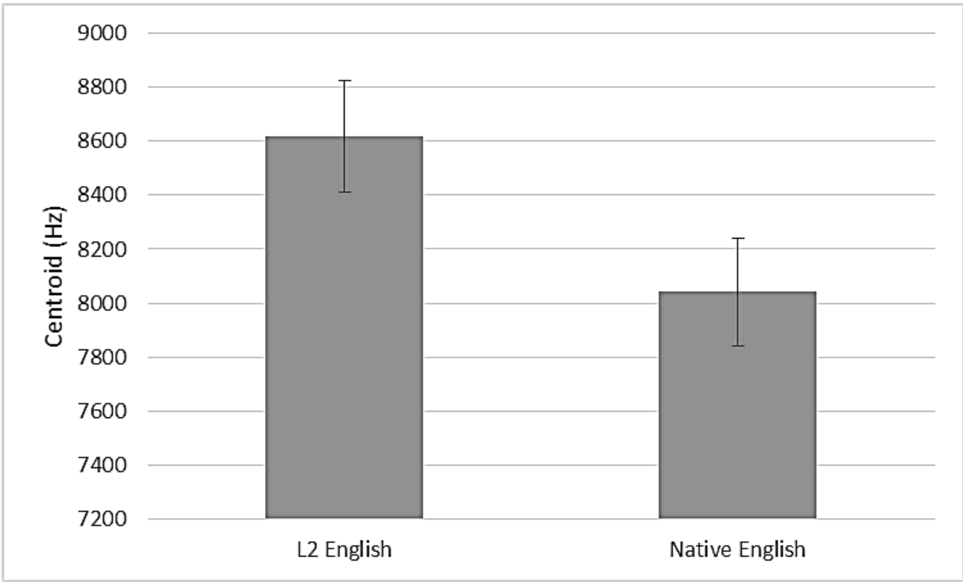

Figure 74. Means of the centroid (Hz) of [z] according to language group from pairwise comparison based on LMM

- SD (in Hz) of [z]

Table 114 shows the means and SEs of the SD (in Hz) for [z] in all contexts based on the numbers of stimuli in each language group - 365 for native English and 190 for L2 English. Tukey's HSD post-hoc test indicates no significant difference between the SD of L2 English [z] and that of native English [z] for all contexts (*p* > 0.05 for all contrasts).

Table 114. Means and SEs of language, language x gender and language x vowel for the SD of [z] from pairwise comparison based on LMM

		L2 English		Native English	
		Mean	SE	Mean	SE
Language	Overall	1811.94	84.65	1782.19	79.89
Language × Gender	Male	1889.61	108.83	1859.86	99.33
	Female	1734.27	96.68	1704.52	98.78
Language × Vowel context	High vowel	1766.04	83.17	1736.29	78.09
	Low vowel	1755.89	92.60	1726.13	86.85
	Back vowel	1913.90	90.09	1884.15	87.27
Language × Vowel context × Gender	Male-high	1843.71	107.43	1813.96	97.61
	Male-low	1833.56	115.10	1803.80	104.98
	Male-back	1991.57	113.37	1961.81	105.64
	Female-high	1688.37	95.67	1658.62	97.61
	Female-low	1678.22	103.74	1648.47	104.51
	Female-back	1836.23	101.18	1806.48	104.55

- Skewness of [z]

Table 115 shows the means and SEs of the skewness for [z] in all contexts based on the numbers of stimuli in each language group - 365 for native English and 190 for L2 English. Tukey's HSD post-hoc test indicates no significant difference between the skewness of native English [z] and that of L2 English [z] for all contexts ($p > 0.05$ for all contrasts).

Table 115. Means and SEs of language, language x gender and language x vowel for the skewness of [z] from pairwise comparison based on LMM

		L2 English		Native English	
		Mean	SE	Mean	SE
Language	Overall	0.63	0.10	0.56	0.09
Language × Gender	Male	0.71	0.12	0.64	0.10
	Female	0.54	0.11	0.47	0.11
Language × Vowel context	High vowel	0.59	0.11	0.52	0.10
	Low vowel	0.67	0.13	0.59	0.12
	Back vowel	0.62	0.10	0.55	0.09
Language × Vowel context × Gender	Male-high	0.67	0.13	0.60	0.12
	Male-low	0.75	0.15	0.68	0.14
	Male-back	0.70	0.13	0.63	0.10
	Female-high	0.51	0.12	0.44	0.12
	Female-low	0.58	0.14	0.51	0.14
	Female-back	0.54	0.11	0.47	0.11

- Kurtosis of [z]

Table 116 shows the means and SEs for the kurtosis of [z] in all contexts based on the numbers of stimuli in each language group - 367 for native English and 193 for L2 English. Tukey's HSD post-hoc test indicates no significant difference between the kurtosis of native English [z] and that of L2 English [z] for all contexts (p > 0.05 for all contrasts).

Table 116. Means and SEs of language, language x gender and language x vowel for the kurtosis of [z] from pairwise comparison based on LMM

		L2 English		Native English	
		Mean	SE	Mean	SE
Language	Overall	2.91	0.56	2.76	0.49
Language × Gender	Male	2.60	0.71	2.44	0.62
	Female	3.22	0.63	3.07	0.62
Language × Vowel context	High vowel	3.23	0.56	3.08	0.51
	Low vowel	3.06	0.75	2.91	0.68
	Back vowel	2.43	0.62	2.28	0.57
Language × Vowel context × Gender	Male-high	2.92	0.71	2.77	0.62
	Male-low	2.75	0.86	2.60	0.77
	Male-back	2.12	0.76	1.97	0.68
	Female-high	3.54	0.63	3.39	0.63
	Female-low	3.37	0.80	3.22	0.77
	Female-back	2.74	0.68	2.59	0.67

- Normalised amplitude of [z]

Table 117: Mean and SD of noise amplitude and vowel amplitude (in dB, averaged across vowels) in two genders for [z]

Language	Gender	Noise amplitude	Vowel amplitude
L2 English	Female	72.04 (4.81)	76.88 (5.29)
	Male	72.46 (3.76)	78.85 (3.99)
Native English	Female	69.65 (3.91)	74.42 (4.38)
	Male	72.84 (4.57)	78.95 (4.13)

Table 117 shows mean noise amplitude and vowel amplitude in two genders for [z] based on the numbers of stimuli in each language group - 365 for native English and 197 for L2 English. Table 118 shows the means and SEs for the normalised amplitude for [z] in all contexts. Tukey's HSD post-hoc test indicates no significant difference between the normalised amplitude of native English [z] and that of L2 English [z] for all contexts (p > 0.05 for all contrasts).

Table 118. Means and SEs of language, language x gender and language x vowel for the normalised amplitude of [z] from pairwise comparison based on LMM

		L2 English		Native English	
		Mean	SE	Mean	SE
Language	Overall	-5.77	0.37	-5.82	0.33
Language × Gender	Male	-6.16	0.46	-6.21	0.40
	Female	-5.38	0.41	-5.43	0.40
Language × Vowel context	High vowel	-5.48	0.39	-5.53	0.38
	Low vowel	-6.00	0.54	-6.05	0.50
	Back vowel	-5.82	0.41	-5.87	0.38
Language × Vowel context × Gender	Male-high	-5.87	0.48	-5.92	0.44
	Male-low	-6.39	0.60	-6.44	0.55
	Male-back	-6.22	0.50	-6.26	0.45
	Female-high	-5.09	0.43	-5.14	0.44
	Female-low	-5.61	0.57	-5.66	0.56
	Female-back	-5.43	0.45	-5.48	0.45

- Onset F2 frequency of [z]

Table 119 shows means and SEs of onset F2 frequency for [z] in all contexts based on the numbers of stimuli in each language group - 383 for native English and 198 for L2 English. Tukey's HSD post-hoc test for language × gender interaction indicates that in female production, the onset F2 frequency of native English [z] is significantly lower than that of L2 English [z] with a moderate effect size (b = -114.89, SE = 42.67, df = 42.12, t = -2.69, p < 0.05, d = 0.24), indicating that in female production, L2 English [z] is more retracted than native English [z]. There is no significant difference between the onset F2 frequency of native English [z] and that of L2 English [z] in language × vowel interaction (p > 0.05 for all contrasts) although in the low vowel context, the onset F2 frequency of native English [z] has tendency to be significantly lower than that of L2 English [z] (p = 0.09). Figure 75 shows that in female production, the onset F2 frequency of native English [z] is lower than that of L2 English [z]. Figure 75 shows the onset F2 frequency of the two language groups in the two genders.

Table 119. Means and SEs of language, language x gender and language x vowel for the onset F2 frequency of [z] from pairwise comparison based on LMM

		L2 English		Native English	
		Mean	SE	Mean	SE
Language	Overall	1834.32	33.12	1781.82	30.89
Language × Gender	Male	1675.27	44.26	1685.18	37.40
	Female	1993.36	37.85	1878.47	37.40
Language × Vowel context	High vowel	2029.93	42.18	2026.98	40.71
	Low vowel	1803.48	59.07	1713.01	55.76
	Back vowel	1669.54	42.85	1605.48	38.67
Language × Vowel context × Gender	Male-high	1854.75	51.98	1914.19	47.48
	Male-low	1649.72	67.18	1621.66	60.22
	Male-back	1521.36	54.52	1519.69	44.94
	Female-high	2205.12	47.11	2139.77	47.62
	Female-low	1957.24	62.38	1804.37	60.23
	Female-back	1817.72	46.39	1691.26	45.19

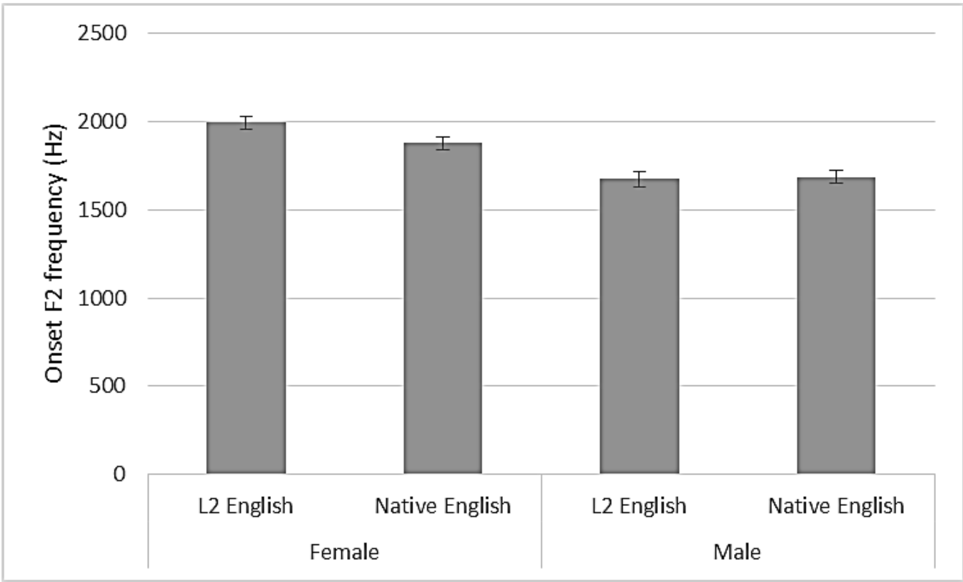

Figure 75. Means of onset F2 frequency (Hz) for [z] according to language group × gender from pairwise comparison based on LMM

Table 120 shows the interpretations of the acoustic measurements for L2 English [z]. The results show no acoustic differences in most contexts, except in the overall context in centroid and for female production in onset F2 frequency.

Table 120. Interpretation of the significant acoustic measurements for L2 English [z]

Position	Measurement	Order	Interpretation	Overall conclusion
Overall	Centroid	L2 > E	L2 English [z] is more fronted than native English [z]	For overall level, L2 English [z] is more fronted than native English [z]
Female	F2	L2 > E	L2 English [z] is more retracted than native English [z]	In female production, L2 English [z] is more retracted than native English [z]

L2 English [ʃ]

- Peak location (in Hz) of [ʃ]

For the peak location (in Hz) of [ʃ], Table 121 shows the means and SEs in all contexts based on the numbers of stimuli in each language group - 527 for native English and 1255 for L2 English. Tukey's HSD post-hoc test for language × gender × vowel interaction indicates that in high vowel context in male production, the peak location of native English [ʃ] is significantly lower than that of L2 English [ʃ] with a moderate effect size (b = -1293.3, SE = 332.67, df = 75.12, t = -3.89, p < 0.01, d = 0.48) suggesting that L2 English [ʃ] is more forward than native English [ʃ]. Figure 76 shows the peak location of the two language groups in the two genders and three vowel contexts.

Table 121. Means and SEs of language, language x gender and language x vowel for the peak location of [ʃ] from pairwise comparison based on LMM

		L2 English		Native English	
		Mean	SE	Mean	SE
Language	Overall	5222.27	130.66	4549.88	200.81
Language × Gender	Male	4882.90	188.08	4129.62	282.14
	Female	5561.63	174.50	4970.14	281.49
Language × Vowel context	High vowel	5116.07	137.67	4353.05	204.41
	Low vowel	5209.26	145.10	4550.49	212.43
	Back vowel	5341.47	175.99	4746.11	266.38
Language × Vowel context × Gender	Male-high	4912.28	191.11	3618.94	285.53
	Male-low	4942.32	201.93	4287.18	294.21
	Male-back	4794.12	250.15	4482.75	371.78
	Female-high	5319.86	178.60	5087.17	279.69
	Female-low	5476.20	189.89	4813.79	294.21
	Female-back	5888.83	232.21	5009.47	371.78

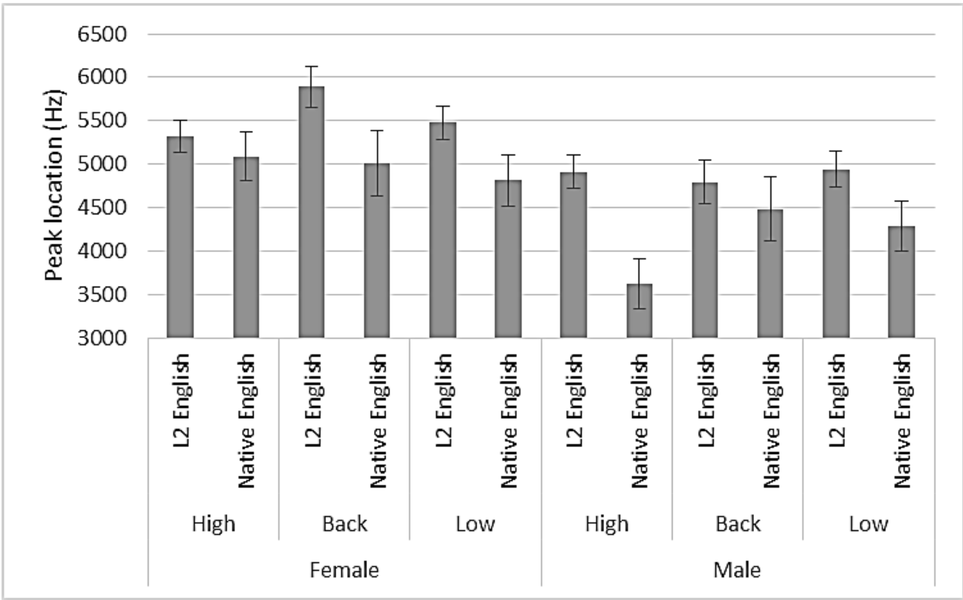

Figure 76. Means of peak location for [ʃ] according to language group × vowel context × gender from pairwise comparison based on LMM

- Centroid (Hz) of [ʃ]

For the centroid (in Hz) of [ʃ], Table 122 shows the means and SEs in all contexts based on the numbers of stimuli in each language group - 537 for native English and 1248 for L2 English. Tukey's HSD post-hoc test for language × vowel interaction indicates that in the low vowel context, the centroid of native English [ʃ] is significantly lower than that of L2 English [ʃ] with a moderate effect size (b = -622.78, SE = 156.86, df = 73.14, t = -3.97, p < 0.01, d = 0.36) and in high vowel context, the centroid of native English [ʃ] is significantly lower than that of L2 English [ʃ] with a small to moderate effect size (b = -438.71, SE = 162.13, df = 73.58, t = -2.71, p < 0.05, d = 0.24). Tukey's HSD post-hoc test for language × gender interaction indicates that in female production, the centroid of native English [ʃ] is significantly lower than that of L2 English [ʃ] with a small effect size (b = -604.17, SE = 218.47, df = 74.32, t = -2.77, p < 0.05, d = 0.20). These results suggest that in female production, in the low vowel and high vowel contexts, L2 English [ʃ] is also more fronted than native English [ʃ]. Figure 77 and Figure 78 illustrate the pairwise comparisons of the two language groups in the two genders and three vowel contexts, respectively.

Table 122. Means and SEs of language, language x gender and language x vowel for the centroid of [ʃ] from pairwise comparison based on LMM

		L2 English		Native English	
		Mean	SE	Mean	SE
Language	Overall	6107.54	83.60	5622.70	130.72
Language × Gender	Male	5821.28	122.63	5455.77	186.23
	Female	6393.81	113.35	5789.64	186.22
Language × Vowel context	High vowel	6066.61	89.44	5627.90	138.34
	Low vowel	6152.51	87.03	5529.74	133.72
	Back vowel	6103.51	93.04	5710.48	144.15
Language × Vowel context × Gender	Male-high	5826.74	128.96	5507.36	193.05
	Male-low	5875.42	125.71	5371.98	188.76
	Male-back	5761.67	133.59	5487.98	198.44
	Female-high	6306.48	119.57	5748.43	193.00
	Female-low	6429.60	116.92	5687.49	188.76
	Female-back	6445.35	123.80	5932.98	198.44

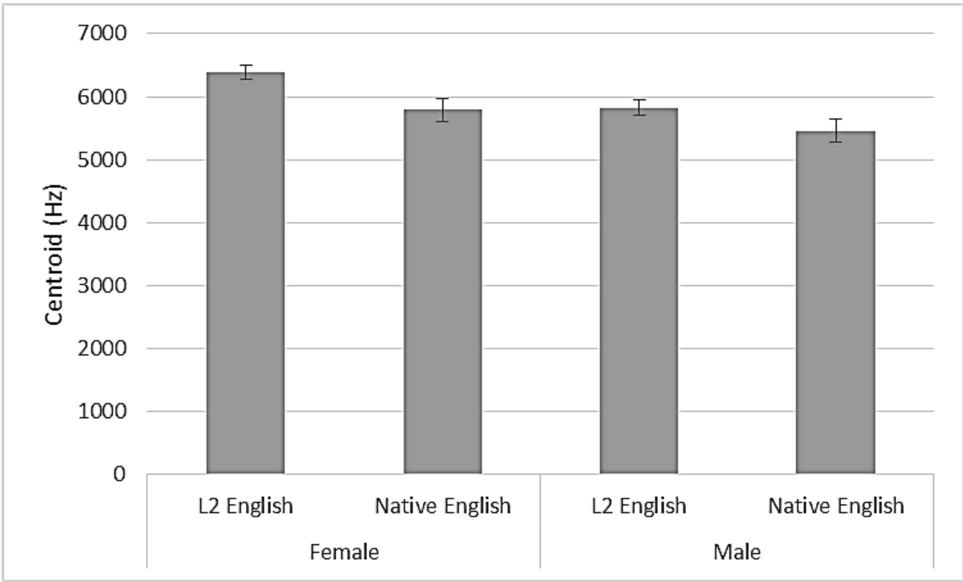

Figure 77. Means of the centroid (Hz) of [ʃ] according to language group × gender from pairwise comparison based on LMM

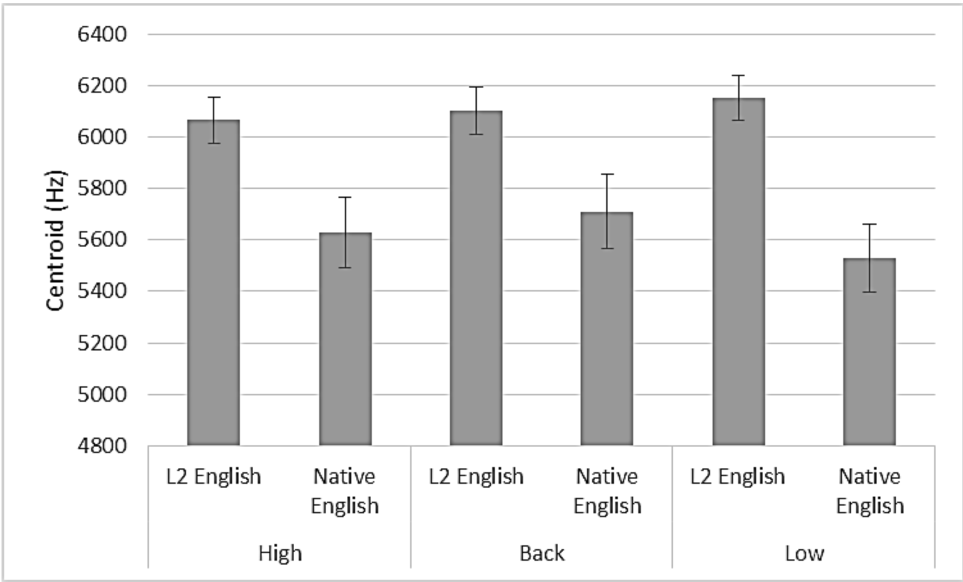

Figure 78. Mean of the centroid (Hz) of [ʃ] according to language group × vowel context from pairwise comparison based on LMM

- SD (in Hz) of [ʃ]

For the SD (in Hz) for [ʃ], Table 123 shows the means and SEs in all contexts based on the numbers of stimuli in each language group - 527 for native English and 1242 for L2 English. Tukey's HSD post-hoc test indicates no significant difference between the SD of native English [ʃ] and that of L2 English [ʃ] for all contexts (*p* > 0.05 for all contrasts).

Table 123. Means and SEs of language, language x gender and language x vowel for the SD of [ʃ] from pairwise comparison based on LMM

		L2 English		Native English	
		Mean	SE	Mean	SE
Language	Overall	2242.58	36.51	2276.34	56.99
Language × Gender	Male	2201.57	53.26	2398.93	80.41
	Female	2283.58	49.30	2153.75	80.39
Language × Vowel context	High vowel	2158.50	37.65	2213.86	57.88
	Low vowel	2215.03	41.49	2234.85	63.61
	Back vowel	2354.20	42.97	2380.31	66.52
Language × Vowel context × Gender	Male-high	2137.01	54.13	2377.18	81.20
	Male-low	2122.71	59.84	2400.31	89.46
	Male-back	2345.00	62.22	2419.30	93.62
	Female-high	2180.00	50.44	2050.54	81.31
	Female-low	2307.34	55.77	2069.40	89.38
	Female-back	2363.40	57.61	2341.32	93.49

- Skewness for [ʃ]

Table 124 shows the means and SEs of the skewness for [ʃ] in all contexts based on the numbers of stimuli in each language group - 531 for native English and 1250 for L2 English. Tukey's HSD post-hoc test indicates no significant difference between the skewness of native English [ʃ] and that of L2 English [ʃ] for all contexts (*p* > 0.05 for all contrasts).

Table 124. Means and SEs of language, language x gender and language x vowel for the skewness of [ʃ] from pairwise comparison based on LMM

		L2 English		Native English	
		Mean	SE	Mean	SE
Language	Overall	1.06	0.05	1.09	0.07
Language × Gender	Male	1.12	0.07	1.08	0.10
	Female	1.00	0.06	1.10	0.10
Language × Vowel context	High vowel	1.19	0.05	1.13	0.08
	Low vowel	1.12	0.05	1.17	0.08
	Back vowel	0.88	0.05	0.97	0.08
Language × Vowel context × Gender	Male-high	1.21	0.08	1.08	0.11
	Male-low	1.17	0.08	1.15	0.11
	Male-back	0.98	0.07	1.01	0.11
	Female-high	1.17	0.07	1.18	0.11
	Female-low	1.06	0.07	1.19	0.11
	Female-back	0.77	0.07	0.93	0.11

- Kurtosis for [ʃ]

Table 125 shows the means and SEs of the kurtosis for [ʃ] in all contexts based on the numbers of stimuli in each language group - 532 for native English and 1246 for L2 English. Tukey's HSD post-hoc test indicates no significant difference between the kurtosis of L2 English [ʃ] and that of native English [ʃ] for all contexts (*p* > 0.05 for all contrasts).

Table 125. Means and SEs of language, language x gender and language x vowel for the kurtosis of [ʃ] from pairwise comparison based on LMM

		L2 English		Native English	
		Mean	SE	Mean	SE
Language	Overall	1.97	0.18	2.14	0.27
Language × Gender	Male	2.08	0.23	2.25	0.30
	Female	1.87	0.22	2.03	0.30
Language × Vowel context	High vowel	2.34	0.22	2.52	0.29
	Low vowel	2.15	0.21	2.32	0.29
	Back vowel	1.43	0.16	1.59	0.25
Language × Vowel context × Gender	Male-high	2.45	0.26	2.62	0.32
	Male-low	2.26	0.26	2.43	0.32
	Male-back	1.53	0.22	1.70	0.29
	Female-high	2.23	0.25	2.40	0.32
	Female-low	2.04	0.25	2.21	0.32
	Female-back	1.32	0.20	1.49	0.29

- Normalised amplitude of [ʃ]

Table 126: Mean and SD of noise amplitude and vowel amplitude (in dB, averaged across vowels) in two genders for [ʃ]

Language	Gender	Noise amplitude	Vowel amplitude
L2 English	Female	70.67 (5.27)	74.78 (5.65)
	Male	73.02 (4.73)	76.86 (5.95)
Native English	Female	68.98 (4.41)	72.60 (4.19)
	Male	72.19 (5.45)	78.61 (4.10)

Table 126 shows mean noise amplitude and vowel amplitude in two genders for [ʃ] and Table 127 shows the means and SEs for the normalised amplitude of [ʃ] in all contexts based on the numbers of stimuli in each language group - 539 for native English and 1246 for L2 English. Tukey's HSD post-hoc test indicates that in male production, the normalised amplitude of native English [ʃ] is significantly lower than that of L2 English [ʃ] with a moderate effect size (b = -2.48, SE = 0.82, df = 73.59, t = -3.02, p < 0.01, d = 0.22), but no significant difference is found between the normalised amplitude of L2 English [ʃ] and that of native English [ʃ] in all vowel contexts (p > 0.05), suggesting that in male production, L2 English [ʃ] is produced with higher effort than native English [ʃ]. Figure 79 shows the normalised amplitude of the two language groups in the two genders.

Table 127. Means and SEs of language, language x gender and language x vowel for the normalised amplitude of [ʃ] from pairwise comparison based on LMM

		L2 English		Native English	
		Mean	SE	Mean	SE
Language	Overall	-4.08	0.32	-5.02	0.49
Language × Gender	Male	-3.95	0.46	-6.43	0.69
	Female	-4.21	0.43	-3.60	0.69
Language × Vowel context	High vowel	-3.67	0.42	-4.46	0.62
	Low vowel	-4.03	0.39	-4.77	0.56
	Back vowel	-4.54	0.39	-5.82	0.56
Language × Vowel context × Gender	Male-high	-3.68	0.57	-6.02	0.81
	Male-low	-3.94	0.53	-6.23	0.75
	Male-back	-4.23	0.53	-7.06	0.76
	Female-high	-3.66	0.53	-2.90	0.81
	Female-low	-4.12	0.49	-3.31	0.75
	Female-back	-4.85	0.49	-4.58	0.76

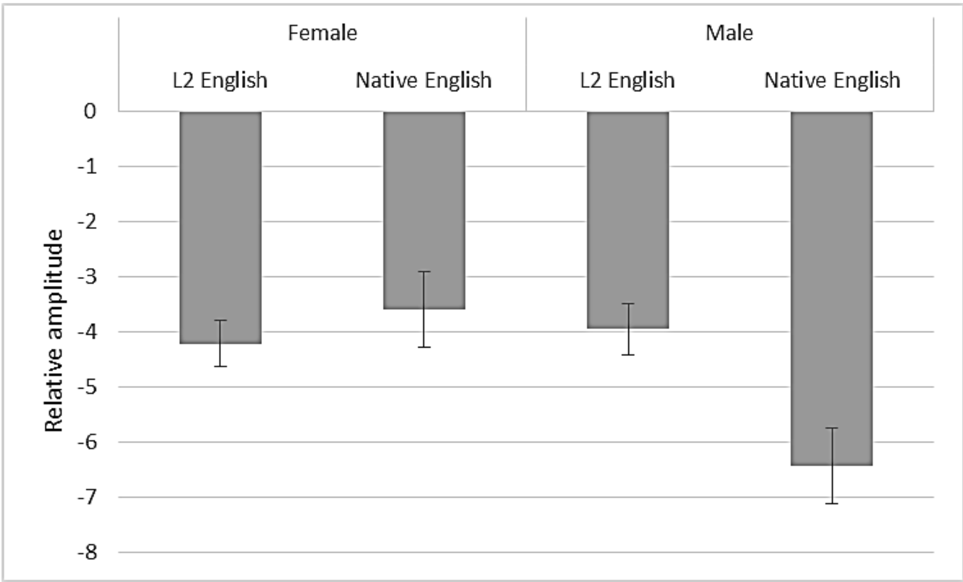

Figure 79. Means of the normalised amplitude of [ʃ] according to language group × gender from pairwise comparison based on LMM

- Onset F2 frequency of [ʃ]

Table 128 shows the means and SEs of the onset F2 frequency for [ʃ] in all contexts based on the numbers of stimuli in each language group - 508 for native English and 1238 for L2 English. Tukey's HSD post-hoc test for the language × gender interaction indicates that in female production, the onset F2 frequency of native English [ʃ] is significantly lower than that of L2 English [ʃ] with a moderate effect size (b = -149.98, SE = 34.29, df = 85.95, t = -4.37, p < 0.01, d = 0.28), suggesting that in female production, L2 English [ʃ] is more retracted than native

English [ʃ]. Tukey's HSD post-hoc test for the language × vowel interaction indicates that in the high vowel context, the onset F2 frequency of native English [ʃ] is significantly lower than that of L2 English /ʃ / with a moderate effect size (b = -98.56, SE = 27.05, df = 72.73, t = -3.64, p < 0.01, d = 0.22), similar to the low vowel context with a moderate effect size (b = -158.25, SE = 36.64, df = 71.57, t = -4.32, p < 0.01, d = 0.30), indicating that in both low vowel and high vowel contexts, L2 English [ʃ] is more retracted than native English [ʃ]. Figure 80 and Figure 81 shows the onset F2 frequency of the two language groups in the two genders and three vowel contexts, respectively.

Table 128. Means and Ses of language, language x gender and language x vowel for the onset F2 frequency of [ʃ] from pairwise comparison based on LMM

		L2 English		Native English	
		Mean	SE	Mean	SE
Language	Overall	2019.10	17.79	1943.93	24.59
Language × Gender	Male	1855.11	22.92	1854.75	31.54
	Female	2183.09	21.68	2033.11	31.79
Language × Vowel context	High vowel	2347.04	23.95	2248.47	29.78
	Low vowel	2048.34	27.43	1890.10	36.33
	Back vowel	1661.93	28.52	1693.23	38.38
Language × Vowel context × Gender	Male-high	2166.93	28.11	2143.17	35.57
	Male-low	1867.90	33.41	1784.46	43.12
	Male-back	1530.52	35.11	1636.62	45.30
	Female-high	2527.15	27.18	2353.78	36.43
	Female-low	2228.78	32.01	1995.73	43.02
	Female-back	1793.35	33.44	1749.84	45.28

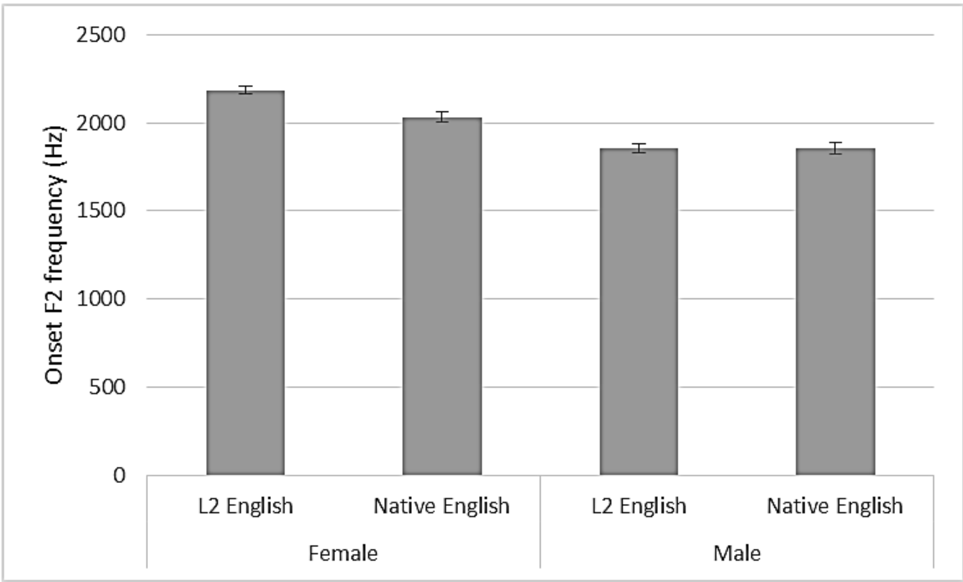

Figure 80. Means of the onset F2 frequency (Hz) for [ʃ] according to language group × gender from pairwise comparison based on LMM

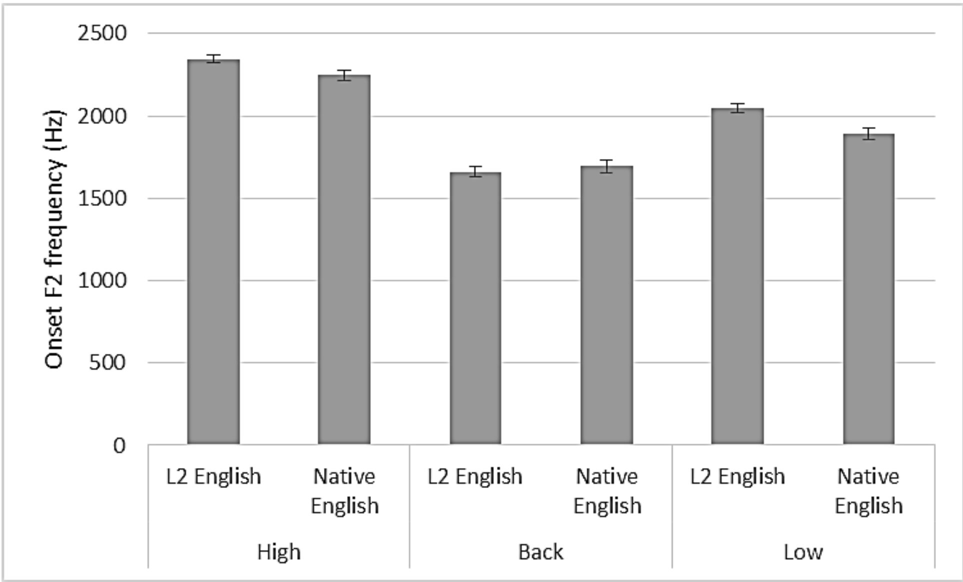

Figure 81. Means of the onset F2 frequency (Hz) for [ʃ] according to language group × vowel from pairwise comparison based on LMM

Table 129 shows the interpretations of the acoustic measurements of L2 English [ʃ]. The results show no acoustic differences in most contexts except in female production for centroid and onset F2 frequency, male production for normalised amplitude, the high vowel context for onset F2 frequency and centroid, low vowel context for onset F2 frequency and centroid and high vowel context in male production for peak location.

Table 129. Interpretation of the significant acoustic measurements for L2 English [ʃ]

Position	Measurement	Order	Interpretation	Overall conclusion
Female	Centroid	L2 > E	L2 English [ʃ] is more fronted than native English [ʃ]	Two possibilities for female production: 1) L2 English [ʃ] is more fronted than native English [ʃ]; and 2) L2 English [ʃ] is more retracted than native English [ʃ]
	F2	L2 > E	L2 English [ʃ] is more retracted than native English [ʃ]	
Male	Normalised amplitude	L2 > E	L2 English [ʃ] is produced with higher effort than native English [ʃ]	In male production, L2 English [ʃ] involves higher effort than native English [ʃ]
High	F2	L2 > E	L2 English [ʃ] is more retracted than native English [ʃ]	Two possibilities for high vowel context production: 1) L2 English [ʃ] is more fronted than native English [ʃ]; and 2) L2 English [ʃ] is more retracted than native English [ʃ]
	Centroid	L2 > E	L2 English [ʃ] is more fronted than native English [ʃ]	
Low	Centroid	L2 > E	L2 English [ʃ] is more fronted than native English [ʃ]	Two possibilities for low vowel context production: 1) L2 English [ʃ] is more fronted than native English [ʃ]; and 2) L2 English [ʃ] is more retracted than native English [ʃ]
	F2	L2 > E	L2 English [ʃ] is more retracted than native English [ʃ]	
High by male	Peak location	L2 > E	L2 English [ʃ] is more fronted, than native English [ʃ]	In high vowel context in male production, L2 English [ʃ] is more fronted, than native English [ʃ]

6.4 Discussion

Before discussing the implications of these results, the overall results were that for [f], L2 English [f] was different from native English [f] in the following contexts: overall context, both genders' productions, all vowel contexts, and back vowel context in both genders' productions. The native Thai [f] was different from native English [f] in the following contexts: overall context, both genders' productions, high and low vowel contexts, and back vowel context in females' production. For [s], L2 English [s] was different from native English [s] in the following contexts: overall context, both genders' productions, all vowel contexts, and the low vowel context in females' production. The native Thai [s] was different from native English [s] in the following contexts: overall context, both genders' productions and all vowel contexts.

The L2 English [v] was different from native English [v] in low vowel context. The L2 English [θ] was different from native English [θ] in both genders' productions and in the high vowel context. The L2 English [ð] was not found to be different from native English [ð] in any phonetic property. The L2 English [z] was found to be different from native English [z] in the overall context and females' production. The L2 English [ʃ] was found to be different from native English [ʃ] in both genders' productions, high and low vowel contexts and high vowel context in males' production.

It is important to remind the reader that the results are based on realisations that were deemed target-like. As the percentages of realisations of shared fricatives that were deemed target-like are large (98.40% approximately), their results might be comparable to those of previous studies. However, as the percentages of realisations of non-shared fricatives that were deemed target-like are small (33.33% approximately), these results might not be completely comparable to results of L2 phonetic properties in previous studies.

Also, the interpretation of [f] and [v] was different from sibilants and dental fricatives in that acoustic results of these two fricatives were interpreted in terms of level of effort due to the small articulation area. The results of sibilants and dental fricatives were interpreted in terms of frontness.

6.4.1 Discussion of L2 shared fricatives

Overall, the results concerning peak location show that L2 English [f] is produced with more effort than native Thai [f] and native English [f], whereas results of kurtosis show contrastive results, i.e. native Thai [f] is produced with more effort than L2 English [f] and native English [f]. Regardless of the direction of difference, what these results highlight is that phonetic properties of L2 English [f] and native Thai [f] are different. Other measurements show different patterns according to context. In terms of gender, for female production, the results for the centroid shows that L2 English [f] and native Thai [f] are produced with more effort than native English [f], but SD shows that native English [f] is produced with more effort than L2 English [f] and native Thai [f]. In male production, the centroid results show that L2 English [f] is produced with higher effort than native Thai [f] whereas normalised amplitude shows that native Thai [f] is produced with highest effort than L2 English [f] and native English [f]. Once again, although these two results might show contrastive results in terms of level of effort, they show that native Thai [f] is more different from L2 English [f] than native English [f], suggesting that L2 English [f] produced by male L2 Thai learners is closer to native English [f] than that of females; this is in contrast to some previous studies which suggest that female performance tends to be closer to the performance of native speakers of the L2 than that of males (e.g. Asher and García, 1969; Piske *et al.*, 2001; Díaz-Campos, 2004; Major, 2004).

In the back vowel context, onset F2 frequency shows that native English [f] is produced with more effort than L2 English [f] for males, and with more effort than L2 English and native Thai [f] for females. However centroid results show that in the back vowel context, native English [f] is produced with less effort than L2 English [f]. In the high vowel context, the interpretations are various: the centroid shows that L2 English [f] and native Thai [f] are produced with more effort than native English [f]; SD shows that native English [f] is produced with more effort than L2 English [f] and native Thai [f]; and normalised amplitude shows that native Thai [f] is produced with more effort than native English [f] and L2 English [f]. In the low vowel, the centroid and normalised amplitude show that L2 English [f] and native Thai [f] are produced with more effort than native English [f] whereas SD shows that native English [f] is produced with more effort than L2 English [f] and native Thai [f].

The onset F2 frequency for the back vowel context in the production of females, SD and centroid for the female production, low vowel context, the high vowel context suggest that the effort involved in the production of L2 English [f] is influenced by native Thai [f] (Lado, 1957; Flege, 1995; Best and Tyler, 2007). The SLM-based hypothesis that phonetic properties of L2 English [f] will be different from native English [f] because Thai [f] differs in its realisations from English [f] is confirmed overall in peak location and kurtosis, female production in centroid and SD and male production in centroid and normalised amplitude, high vowel context in centroid and SD, low vowel context in centroid and SD and back vowel context in centroid, and back vowel context in both genders' production in onset F2 frequency. The peak location in overall context, centroid in female production, normalised amplitude in male production, centroid in high vowel, low vowel and back vowel contexts are higher in L2 English [f] than in native English [f] suggesting that the L2 English [f] in these contexts might be produced with narrower constriction than native English [f] which is correlated with higher effort.

For L2 English [s] production, the results for peak location and kurtosis show that native Thai [s] is produced with the most fronted speech articulators, followed by L2 English [s] and native English [s] respectively. The results can also be interpreted in the way that native Thai [s] is produced with the greatest effort, followed by L2 English [s] and native English [s] respectively The results of peak location and kurtosis suggest that L2 English [s] production differs from both native English [s] and native Thai [s]. None of the previous studies on English fricatives produced by Thai learners (e.g. Brière and Chiachanpong, 1980; Chunsuvimol and Ronakiat, 2000; Chunsuvimol and Ronakiat, 2001; Burkardt, 2008) considered L2 English [s] in initial position, as L2 English [s] impressionistically sounds similar to [s] produced by native speakers of English. The acoustic characteristics of [s] in these three language groups have also received little attention: the study by Roengpitya (2011) was the only acoustic study to include L2 English [s] produced by Thai learners in comparison to native Thai [s] by the same speakers in initial position; however, it did not provide a comparison of these two fricatives. All these researchers seem to agree that L2 Thai learners produce L2 English [s] in a native-like manner because they take the view that there were no differences between native English [s] and native Thai [s]. In the present study, whereas the impressionistic and sound identification studies showed that L2 Thai learners had no difficulty producing L2 English [s], the acoustic result from peak location show that L2 English [s] is produced in between native English [s] and native Thai [s], indicating that L2 learners might discern differences between L1 and L2 sounds produced by native speakers and try to maintain a contrast between their L1 and L2 sounds, resulting in an L2 sound which has phonetic qualities that are different from those of the L1 sound and not identical in terms of phonetic qualities to those produced by native speakers of L2. This results is partially consistent with the accent rating result for L2 English [s], namely in that native Thai [s] was perceived as an accented phone, unlike L2 English and native English [s]. However, the results of accent rating task showed that native listeners could not perceive a difference in the production of native English [s] and L2 English [s]. Hence, the production of L2 English [s] might not be indistinguishable from native-like patterns when acoustic detail is looked at.

Some gender differences in L2 English [s] production are observed. In female production, the results for the centroid, skewness and onset F2 frequency show that native Thai [s] is more forward than L2 English [s] and native English [s] which might also mean that it is produced with higher effort than the other two. In male production, the results for the centroid and onset F2 frequency show that native Thai [s] is the most fronted, followed by L2 English [s] and native English [s] respectively. The interpretation can also be that native Thai [s] is produced with the highest effort, followed by L2 English [s] and native English [s] respectively. Comparing female production of L2 English [s] to male production, the results show that there is no significant difference in L2 Thai female learners' production and native English production for the measurements mentioned. In male production, on the other hand, L2 English [s] is produced in half-way between native Thai [s] and native English [s], with native Thai [s] in the most fronted or is produced with highest effort and native English [s] in the least fronted or is produced with the least effort. The results that female production has a more native-like phonetic quality than male production is consistent with the results of previous studies showing a higher ability in language proficiency for females over males (e.g. Asher and García, 1969; Piske *et al.*, 2001; Díaz-Campos, 2004; Major, 2004).

In terms of vowel context, this study finds that in the centroid and skewness in high vowel context and in the centroid in low vowel context, native Thai [s] is the most fronted, followed by L2 English [s] and native English [s] respectively, suggesting that even though L2 learners cannot attain the qualities of L2 English [s] in these two vowel contexts, they can suppress L1 transfer to some extent. Besides the interpretation in terms of frontness, these results also show that native Thai [s] is produced with highest effort, followed by L2 English [s] and native English [s] respectively. In the low vowel context, there are other two results: skewness shows that L2 English [s] and native English [s] is more retracted than native Thai [s] whereas onset F2 frequency shows that L2 English [s] is more retracted than native English [s] and native Thai [s]. When interpreting these in terms of the level of effort, skewness shows that L2 English [s] and native English [s] is produced with higher effort than native Thai [s] whereas onset F2 frequency show that L2 English [s] is produced with higher effort than native English [s] and native Thai [s]. In the back vowel context, the centroid shows that native Thai [s] is more fronted than native English [s] while L2 English [s] is not different from native English [s]. This can also mean native Thai [s] is produced with higher effort than native English [s] and L2 English [s]. The onset F2 frequency shows that native English [s] is more retracted than L2 English [s] and native Thai [s]. It might be that native English [s] is produced with higher effort than L2 English [s] and native Thai [s]. These results suggest that L2 learners have more native-like acoustic qualities in pronouncing L2 English [s] in the back and high vowel contexts as opposed to the low vowel context. In the low vowel context for females, the normalised amplitude shows that L2 English [s] is more retracted than native Thai [s]. In terms of level of effort, this result shows that L2 English [s] is produced with higher effort than native Thai [s]. This might be because L2 learners notice differences between native English [s] and native Thai [s] and hence trying to produce L2 English [s] in a different way. Thus the SLM hypothesis that phonetic properties of L2 English [s] will be different from native English [s] is confirmed in the overall level in peak location and kurtosis, in female production in centroid and onset F2 frequency, in male production and in high vowel context in centroid, back vowel context in onset F2 frequency and low vowel context in centroid and onset F2 frequency.

6.4.2 Discussion of L2 non-shared fricatives

Regarding the phonetic properties of L2 non-shared fricatives, although SLM-based hypotheses for non-shared fricatives were disconfirmed in previous chapters due to low degree of target-like realisations of these sounds, it seems that the number of acoustic measurements needed to differentiate realisations of native English sounds that were deemed target-like from those of L2 English sounds might depend on whether the target fricatives are voiceless or voiced. Zero to two acoustic measurements were needed to show differences in realisations of voiced target fricatives that were deemed target-like, whereas those for voiceless target fricatives, three to four acoustic measurements were needed to show differences between these two language groups in different contexts.

Starting from voiceless non-shared fricatives, in female production, the centroid, normalised amplitude and SD values suggest different results: 1) L2 English [θ] is more fronted than native English [θ]; 2) L2 English [θ] is more retracted than native English [θ]; and 3) native English [θ] is involves higher effort than L2 English [θ]. The centroid result might also suggest that L2 English [θ] is produced with higher effort than native English [θ] whereas the result of SD suggest the opposite. In male production, on the other hand, the normalised amplitude suggests that L2 English [θ] is produced with higher effort than native English [θ]. These results suggest that L2 English [θ] production differs from native English [θ] for both genders. In the high vowel context, the SD of [θ] is higher for native English [θ] than for L2 English [θ], suggesting that L2 English [θ] is more retracted than native English [θ]. It might also mean that native English [θ] is produced with higher effort than L2 English [θ].

For L2 English [ʃ], in female production, high vowel and low vowel contexts, the results for the centroid indicate that L2 English [ʃ] is more forward than native English [ʃ] whereas the opposite result is found for the onset F2 frequency. It might also be that L2 English [ʃ] is produced with more contact and has narrower constriction and might be more lip spreading than native English [ʃ] as the frequencies are higher. In male production, in contrast, the normalised amplitude suggest that L2 English [ʃ] is produced with higher effort than native English [ʃ]. In the high vowel context in male production, peak location value shows that L2 English [ʃ] is more fronted than native English [ʃ]. The other interpretation could be that L2 English [ʃ] is produced with higher effort than native English [ʃ]. In female production, low vowel, high vowel and high vowel in male production, the L2 English [ʃ] might potentially be produced with narrower constriction and more lip spreading than native English [ʃ].

For voiced non-shared fricatives, starting from L2 English [v], the result for onset F2 frequency suggests that L2 English [v] is produced with more effort than native English [v] in the low vowel context. For L2 English [ð], none of the acoustic measurements showed differences between the two language groups, which may suggest L2 attainment in the acoustic manifestation of the target-like realisations (Flege, 1995; Best and Tyler, 2007). It is worth noting, however, that in the accent rating task, the target-like L2 English [ð] sounded more accented than the native English [ð], indicating that some other phonetic properties of L2 English [ð] may have led to this. These include duration, overall noise amplitude and locus equation. Similar to the results of Bohn and Flege (1992), an English /ɛ/ produced by German learners of English was less intelligible than that produced by native speakers of English, but there were no differences in acoustic properties in their acoustic analysis. According to Bohn and Flege (1992), it is possible that the perception of native listeners of L2 was influenced by some acoustic characteristics that were not analysed in their study. Hence a future study might include more acoustic measurements to investigate L2 English fricatives, especially L2 English [ð] such as the ones described above.

For L2 English [z], the centroid values suggest that L2 English [z] is more fronted than native English [z] in the overall context, but in female production, the onset F2 frequency shows that L2 English [z] is more retracted than native English [z]; thus, female learners did not always outperform male learners, in contrast to the results of previous studies (e.g. Asher and García, 1969; Piske *et al.*, 2001; Díaz-Campos, 2004; Major, 2004). The results of these two contexts can also mean that L2 English [z] is produced with higher effort than native English [z]. Overall, the results suggest that production of L2 non-shared fricatives that was deemed target-like had almost completely similar in acoustic characteristics to that of native English production, as opposed to that of L2 shared fricatives.

6.5 Conclusion

In this chapter, a phonetic investigation of L2 production was undertaken. The overall results showed that L2 shared fricatives exhibit greater phonetic differences from those produced by native speakers of both languages, as opposed to L2 non-shared fricatives. The phonetic properties of L2 shared fricatives had a large proportion of target-like realisations but were found to be different from their L1 counterparts, which partially supports SLM-based hypotheses regarding shared (similar) sounds being is difficult to produce. However, SLM-based hypotheses for non-shared (different) sounds are disconfirmed based on low percentages of realisations that were deemed target-like. Hence SLM makes more consistent predictions for shared sounds rather than non-shared sounds. In the next section, all the results from the four types of analysis are discussed in relation to CAH and SLM together with a sociolinguistic perspective, and implications of the study are offered.

Chapter 7. Discussion and conclusion

7.1 Introduction

The aim of this thesis was to investigate English fricative production by L2 Thai learners and to explore linguistic and social factors that correlate with target-like realisations. This chapter aims to discuss the results of this study and to find out the extent to which the four models, the Contrastive Analysis Hypothesis (CAH), the Perceptual Assimilation Model-L2 (PAM-L2), the Speech Learning Model (SLM) and the Second-Language Linguistic Perception (L2LP) can account for the results of this study. According to the reviews of models and predictions based on CAH and SLM in Chapter Two, the hypotheses are set out as follows.

For the impressionistic and sound identification analyses, the prediction based on CAH is that the production of shared sounds is easy, whereas the production of L2 non-shared sounds is difficult. Based on impressionistic analysis this was meant to be shown in the following way: the percentage of target-like realisations of L2 Thai learners for L2 shared fricatives was expected to be high and that for target-like realisations was expected to be no different from that of native speakers of L2. Equally, in the sound identification analysis the percentage of target-like realisations of L2 Thai learners for L2 shared fricatives was expected to be high.

SLM-based hypothesis predicts that it is easier to produce an L2 non-shared sound in a native-like manner, as opposed to L2 shared sound. Thus, for the accent rating tasks, SLM yielded predictions that the production of L2 shared sounds would have low scores for native-likeness, indicating they are difficult to produce, whereas the production of L2 non-shared sounds would have high scores for native-likeness, indicating they are easy to produce. For the acoustic analyses, the hypotheses derived from SLM stated that the phonetic properties of L2 shared sounds would be different from those of the production by native speakers of L2, but for L2 non-shared sounds, the characteristics would be similar to those of the production by native speakers of L2.

Summary of results

A series of analyses were carried out, as reported in the previous chapters. The main set consisted of an impressionistic analysis of L2 Thai learners' production of English fricatives using a word list, followed by a sociolinguistic questionnaire which probed factors such as length of L2 exposure, LOR, gender, ideal L2 self, ought-to L2 self, L2 learning experience, anxiety, word frequency and vowel context that might affect their target-like L2 English production. The results showed that for shared fricatives, no significant difference in the proportions of target-like L2 /f, s/ productions was found in any language pairs. While for L2 English [f] production, no significant factor in target-like production was found, L2 English exposure and a back high vowel context as compared to a front low vowel context were found to be negatively related to the proportion of target-like L2 English /s/ production. For non-shared fricatives, the proportions of target-like L2 English /v, θ, ð, z/ productions were found to be significantly lower than those of native English productions, whereas no significant difference between the proportion of target-like L2 English /ʃ/ and native English /ʃ/ was found. The proportion of target-like L2 English /v/ was found to be negatively correlated with male speakers and L2 anxiety, but positively correlated to ideal L2 self. The proportion of target-like L2 English /θ/ was found to be positively correlated to ideal L2 self but negatively correlated to L2 anxiety. The proportion of target-like L2 English /ð/ was only found to be positively correlated to LOR. The proportion of target-like L2 English /z/ was found to be positively correlated to ideal L2 self, LOR, back high vowel context as compared to the other three vowel contexts and front high vowel context as compared to the front low vowel context; however it was found to be negatively correlated with male speakers and word frequency. The proportion of target-like L2 English /ʃ/ was found to be positively correlated with word frequency, ideal L2 self, back mid to low vowel context as compared to front low vowel context and back high vowel context as compared to front low vowel context; however it was found to be negatively correlated with LOR and L2 experience.

In Chapter Four, an analysis of L2 English fricatives was done via the sound identification task. A group of native speakers of English listened to a set of stimuli generated from a 10% randomised list from the vowel /i/ and identified the sound they heard from 11 options. The results showed high rates of correct sound identification for L2 English /f, s/ but low rates for L2 English /v, θ, ð, z, ʃ/.

In Chapter Five, an accent rating task was used to analyse L2 English fricatives in terms of native-likeness. A group of native speakers of English listened to a set of stimuli that was generated from 10% target-like realisations in the /i/ vowel context and rated the sound they heard on the nine-point Likert scale. The results showed that native English [f] and native Thai [f] were more accented than L2 English [f], and native Thai [s] was more accented than native English [s] and L2 English [s]. For non-shared sounds, although listeners expressed no difference in the accent rating between L2 English [v, θ] and their native English counterparts, L2 English [ð, z, ʃ] were found to be more accented than their native English counterparts.

In Chapter Six, the target-like realisations from Chapter Three were acoustically analysed. Seven acoustic measurements were used: peak location, centroid, SD, skewness, kurtosis, normalised amplitude and onset F2 frequency. The acoustic characteristics of L2 English [f] were found to be different from those of native English [f] in the overall context, both genders' productions, all vowel contexts, and back vowel context in both genders' productions. Its characteristics were found to be different from those of native Thai [f] in overall context, male's production and high vowel context. The acoustic characteristics of L2 English [s] were found to be different from those of native English [s] in the overall context, males' production and all vowel contexts. Its characteristics were found to be different from those of native Thai [s] in the overall context, both genders' productions, all vowel contexts, and the low vowel context in females' production. For L2 English [v], only one acoustic measurement was found to be different from that of native English [v] in the low vowel context. The acoustic characteristics of L2 English [θ] were found to be different from those of native English [θ] in both genders' productions and in the high vowel context. For L2 English [ð], no difference in acoustic measurements were found between L2 English and native English. The acoustic characteristics of L2 English [z] were found to be different from those of native English [z] in the overall context and females' production. The acoustic characteristics of L2 English [ʃ] were found to be different from those of native English [ʃ] in both genders' productions, high and low vowel contexts and high vowel context in male's production.

7.2 Discussion and implications of the study

Based on the impressionistic analysis, no significant differences in the proportion of L2 English /f/ or /s/ productions that were deemed target-like were found across the three language groups (native Thai, native English and L2 English), and there were high percentages of realisations of these two sounds that were deemed target-like (99.39% for L2 English /f/ and 97.40% for L2 English /s/). In the sound identification analysis, the percentages of correct identifications of /f/ and /s/ in L2 English were high (82.89% for L2 English /f/ and 91.56% for L2 English /s/). The CAH-based hypotheses which predict that L2 learners would find L2 sounds that exist in their L1 sound system easy to produce are confirmed for both analyses. PAM-L2 and L2LP could also explain this success of L2 English /f/ and /s/ in that L2 Thai learners matched the native English /f/ and /s/ with their given native Thai /f/ and /s/ in perception and this helps them to produce these two sounds. The existence of L1 sounds seems to promote L2 production through 'positive transfer' (Major, 1987, p. 64).

In contrast, the results of the impressionistic analysis showed that the proportion of /v, θ, ð, z/ productions by L2 Thai learners that were deemed target-like was significantly lower than those produced by native speakers of L2 and was generally low (13.20% for L2 English /v/, 30.48% for L2 English /θ/, 7.83% for L2 English /ð/ and 21.60% for L2 English /z/). In the sound identification analysis, the results that all L2 non-shared fricatives /v, θ, ð, z, ʃ/ had low percentages of correct identification (64.89% for L2 English /v/, 34.24% for L2 English /θ/, 12.66% for L2 English /ð/, 37.78% for L2 English /z/ and 52.22% for L2 English /ʃ/). These results confirm the CAH-based hypotheses which predict that the non-existence of L2 sounds in the L1 sound system will lead to difficulty in L2 sound production. The results of these two analyses seem to give support to many studies which claim that CAH is useful in predicting errors of L2 learners at the phonological level (e.g., Brière and Chiachanpong, 1980; Musau, 1999).

From the impressionistic results for most non-shared fricatives, the most common replacement for L2 English /v/ was [w] (73%); for L2 English /θ/ it was [t] (48%); for L2 English /ð/ it was [d] (81.17%); and for L2 English /z/ it was [s] (78.2%). These substitutions are phones from the native Thai sound system. This might be due to the equivalence classification mechanism proposed by SLM, which predicts that when the L2 learners link L1 and L2 sounds in their perception, they will produce L1 and L2 sounds similarly in production as well. When this happens, the formation of an L2 category is blocked, and this perception is reflected in L2 non-shared sound production that is mostly produced using L1 sounds. PAM-L2 could also account for this difficulty in learning L2 English fricatives if one assumes that L2 Thai learners perceived these fricatives as equivalent to their L1 phonological categories, resulting in the replacing the L2 target fricative with their L1 sound.

Regarding CAH, the main results of both impressionistic and sound identification analyses seem to support the notion of CAH that L2 learners will transfer their L1 sounds in L2 sound production. However, even the results that were summarised as accurately predicted by a CAH-based hypothesis were not completely accurate, i.e. not all realisations for shared sounds were 100% target-like and not all realisations for non-shared sounds were 0% target-like. In the impressionistic analysis, the results that were accurately predicted were those of /f/ (99.39%), /s/ (97.4%), /v/ (13.2%), /θ/ (30.48%), /ð/ (7.83%) and /z/ (21.6%). For the sound identification analysis, those results that were accurately predicted by a CAH-based hypothesis were all sounds: /f/ (82.89%), /s/ (91.56%), /v/ (64.89%), /θ/ (34.24%), /ð/ (12.66%), /z/ (37.78%) and /ʃ/ (52.22%).

Substitutions for each target sound were various. For example, in the impressionistic analysis, L2 English /v/ was produced as [v, f, b, w, t, d ð, p]. However, a CAH-based hypothesis can only predict that the /v/ will be difficult for L2 Thai learners as it does not exist in the native Thai sound system, but it cannot explain nor predict the substitutions of the target sounds. In other words, it cannot account for the variability of the L2 sound productions by L2 learners (Dickerson, 1975; Sridhar, 1980).

As for L2 English /ʃ/ production in the impressionistic analysis, due to its non-existence in the L1 sound system, a CAH-based hypothesis predicted that L2 learners would find it difficult to produce, but this hypothesis was disconfirmed as the percentage of realisations of L2 English /ʃ/ that were deemed target-like was high and no different from those of native English /ʃ/. Hence, CAH failed to account for the production of L2 English /ʃ/ based on the impressionistic analysis. The high proportion of target-like production might be due to the existence of native Thai /t͡ɕʰ/, which tends to share the place of articulation of native English /ʃ/ as can be seen in the work of Brière and Chiachanpong (1980) who symbolised [t͡ʃ] to represent /t͡ɕʰ/ or 'ช' in Thai. It is possible that the fricative part of this Thai affricate facilitates the production of L2 English /ʃ/. SLM could explain this situation in that when L2 Thai learners discern differences between native Thai /t͡ɕʰ/ and L2 English /ʃ/, then the new L2 sound is learned. However, although most L2 English /ʃ/ realisations were transcribed as target-like in the impressionistic analysis, in the sound identification task, most of these tokens were heard as [t͡ʃ] (97.78%) by native listeners of English. It may be the case that the native listeners were more sensitive to the presence of an affricate variant, which is close to the [t͡ʃ] realisation of /t͡ɕʰ/ in Thai, while the author's transcription may have been more influenced by the expected target (/ʃ/). This highlights the importance of using multiple listeners and data analyses techniques to judge L2 listeners' production.

In contrast with /ʃ/, which triggered more target-like judgements based on the impressionistic analysis than the sound identification task, the remaining sounds under investigation triggered lower percentages of target-like judgements than those in sound identification analysis.

Apart from differences in the linguistic demands of each task, the design of each will have influenced the results. For instance, in the impressionistic analysis, the transcriber could listen to whole words whereas in the sound identification analysis, the group of listeners only heard the target fricative and a part of the following vowel. If the listeners could have listened to whole words, the percentages of target-like L2 non-shared fricatives might be changed, but the influence of other sounds in the words would have played a role too. Another main difference relates to the nature of the impressionistic analysis, which allows for a free IPA transcription, while the sound identification required an answer out of 11 options only, which limited the responses of the group of listeners. It is possible that the listeners might have heard a realisation that fell in between the presented options, but could not express that in their answers.

The results of higher percentages of target-like L2 productions in non-shared sounds of the group of English listeners suggest the broader proportion of acceptable variants of the native speakers of English who are exposed not only to native speakers of English but also to various groups of non-native speakers.

Regarding sociolinguistic factors, the most outstanding factor that was found to be positively correlated with target-like realisations of L2 non-shared sounds /v, θ, z, ʃ/ was the ideal L2 self. Whereas CAH, SLM, PAM-L2 and L2LP do not focus on motivation as a contributor to L2 speech, this result suggested that for L2 sounds which do not exist in the L1 phonological system, level of attainment depends on the extent to which L2 learners strive for the ideal L2 self.

Next we look at results from ratings of native-likeness. Starting with shared sounds and looking at the accent rating task, [f] received higher scores of native-likeness than native English [f] and native Thai [f] and this was significant in terms of degree of sensitivity; this suggests that L2 Thai learners can produce L2 English [f] with native-like quality, which disconfirms the SLM prediction that this sound is difficult. For realisations of L2 English [s] that were deemed target-like, although the median scores of native-like ratings were higher for native English [s] than for native Thai [s] and L2 English [s], the degree of sensitivity towards L2 English [s] and native English [s] were not different from one another whereas native Thai [s] was found to have different degree of sensitivity than native English [s] and L2 English [s]. This suggests that a new L2 sound category was formed; hence this result also disconfirms the SLM-based hypothesis that the shared sound is a difficult sound to produce in a native-like manner. As both L2 English [f] and [s] were produced in a native-like manner, the accent rating results for realisations of L2 shared fricatives that were deemed target-like disconfirm the SLM-based hypotheses. The results of L2 shared fricatives reveal that the investigation of native Thai sound production helps the exploration of L2 English sound production. For example, in the production of L2 English /s/, the impressionistic and sound identification results might lead to the conclusion that success in the production of L2 English /s/ is due to positive transfer from native Thai /s/; however, the result that native Thai [s] sounded accented, whereas native English [s] and L2 English [s] did not sound different from one another, suggests that the production of L2 English /s/ is not the same /s/ as in native Thai /s/ and is thus not the complete result of positive transfer from native Thai /s/.

Only a small proportion of non-shared sounds as produced by Thai L2 learners were deemed target-like. While there was no difference in the accent rating between L2 English [v, θ] and their native English counterparts, L2 English [ð, z, ʃ] were found to be more accented than their native English counterparts. The attainment in the target-like L2 English [v, θ] production suggests that some non-shared sounds are more learnable for L2 learners than some other non-shared sounds and that acquisition of L2 non-shared sounds is possible.

For acoustic analyses, starting from L2 English [f], it was found that the acoustic characteristics of L2 English [f] were different from those of native English [f] in the following contexts: overall context, both genders' production, all vowel contexts and back vowel context in both genders' production. The SLM-based hypothesis accurately predicted that it would be difficult for L2 learners to achieve the fine phonetic detail of native [s] when this sound is shared with the L2 - the phonetic properties of L2 English [f] would be different from those of native English [f]. The SLM-based hypothesis also predicted that L2 English [f] would be difficult due to the difference in phonetic properties between native English [f] and native Thai [f]; this was confirmed in the following contexts: both genders' production, high vowel context, low vowel context and back vowel context in female's production suggesting that native English [f] is not identical to native [f] (Flege, 1992) for L2 Thai learners in these contexts. However, in other contexts, no difference in phonetic properties of realisations of native English and L2 English were found. SLM assumptions were disconfirmed in these contexts. In addition, in the overall context, male production and high vowel context, a difference in phonetic properties was found between realisations of L2 English and native Thai [f], suggesting that L2 learners were maintained a separation as predicted by SLM.

In the case of L2 English [s], it was found that the acoustic characteristics of L2 English [s] were different from those of native English [s] in the following contexts: overall context, males' production, high vowel context, low vowel context, back vowel context. The SLM-based hypothesis accurately predicted that L2 English [s] would be difficult in these contexts - the phonetic properties of L2 English [s] would be different from those of native English [s]. The phonetic properties of native English [s] were also different from those of native Thai [s] in these contexts: overall context, both genders' production, the high vowel context, the low vowel context and the back vowel context suggesting that the L2 English [s] is not identical sound (Flege, 1992). In other contexts, no difference was found between the phonetic properties of native English [s] and L2 English [s] sounds. SLM assumptions were disconfirmed in these other contexts. In the results of the following contexts: overall, female production, male production, all vowel contexts and low vowel context by female speakers, there were phonetic characteristic differences between L2 English and native Thai [s], suggesting the maintenance of contrast between realisations of L2 English [s] and native Thai [s] according to SLM. From the results of L2 English [f] and [s], the phonetic qualities of target-like L2 shared sounds were found to be different from those of L1 (learners' native language) such as peak location of native Thai [f] that was found to be different from that of L2 English [f] across context suggesting that L2 shared sounds are not entirely influenced by L1 native sounds.

For the results of these non-shared fricatives, the SLM-based hypothesis for different fricatives based on the acoustic analysis cannot be verified because of the small proportion of target-like tokens in the impressionistic and sound identification analyses. However, for these target-like realisations, the acoustic characteristics of sounds that were different from those of native English were the following: L2 English [v] in the low vowel context, [θ] in both genders' production and the high vowel context, L2 English [z] in the overall context and for female production and L2 English [ʃ] in both genders' production, the high vowel context and the low vowel context; however, the acoustic results for L2 non-shared fricatives in the other contexts showed a certain degree of L2 attainment, if the non-target-like realisations were set aside. In addition, the acoustic characteristics of L2 English [ð] realisations were no different from those of native English, suggesting L2 attainment in these seven acoustic measurements in this L2 sound production.

The phonetic qualities of target-like voiced L2 non-shared sounds are more similar to those of L1 sounds produced by native speakers of L2 compared with the voiceless set. As can be seen from the results of this study, target-like L2 English [v] had one acoustic measurement that was different from that of native English counterpart; target-like L2 English [z] had two measurements that were different from those of native English counterpart whereas no different measurements were found for those of L2 English [ð]. For target-like voiceless L2 non-shared sounds, i.e. target-like L2 English [θ] and [ʃ], and target-like L2 shared sounds, including target-like L2 English [f] and [s], a higher proportion of phonetic qualities in the L2 productions differ from those produced by native English participants. This suggests that the target-like realisations of voiced consonants are more native-like than those of voiceless ones.

From the acoustic analysis, the gender and vowel context were investigated as factors to find out phonetic property differences between each language pair and these two factors were shown to be relevant in many contexts. This suggests that it is difficult to establish acoustic similarities for all measurements in all contexts, especially when there are many acoustic measurements. This is evident in the results for the acoustic characteristics of target-like L2 English [f, s], which showed some similarities in some vowel contexts and gender but not all vowel contexts in all genders. This study is an example showing that when dealing with acoustic data, it is important to include other factors such as vowel contexts and gender as independent variables to control for them before summarising the data. It can be argued that it is inappropriate to conclude the presence of acoustic differences based only on the global level (language group) when there may also be significant differences in the acoustic qualities related to gender and/or vowel contexts. Even though SLM can be used to generate predictions, the predictions do not take the other factors, such as vowel context and gender into account. From the main acoustic results, many results that supported SLM were context-dependent. For example, SLM-based hypothesis accurately predicted the results of L2 English [s] in the overall context, males' production and all vowel contexts but not in other contexts, such as in females' production. Many studies have also found the importance of other factors to the acoustic difference between languages, such as the difference in F1 between native and L2 English SQUARE vowel productions in the work of Almbark (2012) that was found when gender was involved as a factor.

7.3 Contribution

This thesis has investigated L2 English fricative production by L2 Thai learners. The first contribution is to the acoustic study of L2 fricatives. In terms of the phonetic qualities of L2 sounds, most previous studies have been carried out on vowels and stops, but not for fricatives. One of the reasons is that L2 fricatives are often replaced by sounds with other manners of articulation, which causes difficulty in using the same set of acoustic measurements for fricatives. In this study, this problem was solved by including only realisations that were deemed target-like in the impressionistic analysis in the acoustic investigation at the expense of having a reduced proportion of tokens as produced by the learners.

This study is also among the small number of studies that compare L2 production with production by native speakers of both languages. This is the case for L2 shared fricatives as L2 English /f, s/ have native Thai counterparts. Whereas having native English sounds to compare with L2 English sounds helps investigate the degree of L2 attainment, having native Thai sounds helps explore if the production of L2 English sounds is influenced by native Thai sounds.

The next contribution of this study is the investigation of target-likeness of L2 English fricative production by L2 Thai learners using a sound identification analysis, which is the first study in the study of L2 English fricative production by L2 Thai learners. In Chapter Four, most results were consistent with the results of the impressionistic study, except for the production of L2 English /ʃ/. It is possible that native speakers of English might better distinguish L2 English /ʃ/ from native English /ʃ/ as opposed to a listener with a shared linguistic background as L2 learners, suggesting that the perception of native speakers of L2 and native speakers of L1 regarding L2 sound production might be different from one another.

This study is also the first to investigate the degree of native-likeness in the realisations of L2 English fricative by Thai learners that are deemed target-like using accent-rating analysis. The results of the accent rating analysis highlight the fact that the production of L2 English [s] of Thai learners is not completely due to positive transfer as is commonly believed (Ronakiat, 2002; Kanokpermpoon, 2004). This also suggests that it is not necessarily the case that all realisations of sounds which might have a low degree of target-likeness or a low score for sound identification will have a low degree of native-like accentedness in their realisations. For example, even though L2 English [v, θ] had low degrees of target-likeness and low scores for sound identification, their realisations that were deemed target-like were also native-like, suggesting that producing L2 non-shared sound in a native-like manner is possible.

In the accent rating and acoustic analyses, only target-like tokens were measured for their native-likeness which is uncommon for sound analysis in L2 phonology. The analysis of only target-like tokens answers the question of whether it is possible to learn an L2 sound which is target-like, native-like and has native-like acoustic qualities. For example, the results from the accent rating task showed that even though the percentages of target-like realisations from the impressionistic analysis of /v/ and /θ/ were not high, these target-like tokens sounded native-like, implying that the chance of producing these L2 sounds in a manner perceived as native-like is possible.

The next contribution is the investigation of the relationship between many factors in terms of target-like production. In this study, nine factors – LOR, vowel context, gender, ideal L2 self, ought-to L2 self, L2 learning experience, L2 anxiety, L2 exposure and word frequency – were explored. The internal driver, ideal L2 self, seems to play the biggest role in L2 non-shared production. Most results of non-shared fricatives suggested that in the group of L2 learners with extensive background of using the L2 in their home country where less native-like input is available, it is necessary for them to have their own drive to be better at L2 sound production.

The next contribution of this study is the focus of L2 learners in an L2 country with extensive experience of the L2 as a foreign language in their home country. This group of subjects might be close to learners as described in SLM; however, SLM focuses on the L2 learning of L2 learners with an extensive period of stay in the L2 country. The learners in SLM are assumed to be exposed to L2 input produced by native speakers of L2. This input tends to promote their L2 speech, enabling them to approximate native-like level, especially when they arrive in the L2 country at an early age. The L2 learners are different in that the input received will mostly have been from language teachers with a similar language background to them. In other words, the input that this group of L2 learners receive will contain fewer native-like qualities as opposed to L2 learners considered in SLM. This makes the language background of this group of L2 learners close to L2 learners in their home country.

Additionally, the results of this thesis are also relevant to the establishment of similarity and difference between L1 and L2 sounds that is context-dependent, i.e. that is sensitive to 1) listener, 2) contextual effects and 3) types of analysis. Regarding the first point, establishing similarity between L1 and L2 sounds depends on who the listener is. For example, in the /s/ production, even though /s/ in native Thai and native English was judged as target-like when perceived by the author, not all of these realisations were perceived as /s/ by the native speakers of English. The second point relates to the linguistic context. For example, in the acoustic analysis, characteristics of realisations of native English [s] that were deemed target-like were similar to those of native Thai [s] in many contexts but also different in many other contexts. For the last point, the L1 and L2 sound comparison is also dependent on types of analysis. For instance, in the broad transcription, native Thai and native English /s/ are considered as similar in terms of being represented by the same IPA symbol and when analysed by using impressionistic and sound identification analyses; however, they were judged as different in the accent rating analysis. When comparing L1 and L2 sounds, researchers need to specify the contexts of similarity such as type of analysis, group of judges and other contexts. The similarity of L1 and L2 sounds in one context might not be applicable to the similarity in other contexts.

7.4 Limitations of the study

In addition to the contribution of this study to the field of L2 phonology, there are five limitations in this study. The first limitation is that only fricatives in the onset position were analysed. The L2 English fricative production here hence might not represent fricative production as a whole, since it was limited to only the production in the onset position. However given that there were four analyses of L2 production in this study and in Thai, fricatives are allowed only in the initial position, fricatives in the this position hence have priority over those in the other positions.

The second limitation is on the sociolinguistic analysis, i.e. only one level of factors was analysed instead of having interactions of factors. Many studies showed significant effects in the interaction of factors, such as the significant language × similarity interaction (Baker and Trofimovich, 2008), L2 experience × vowel interaction (Flege *et al.*, 1997) and stimulus type × word frequency interaction (Imai *et al.*, 2005). However, when there are many factors of interest, it can be difficult to find interaction for all factors as the statistical model gets complicated. It might be worth running a model with interaction when smaller number of factors is in focus.

For the third limitation, in the acoustic analysis, only seven acoustic measurements: peak location, four spectral moments, normalised amplitude and onset F2 frequency were investigated. In the study of acoustic characteristics of fricatives, many other measurements have been used, such as duration (Crystal and House, 1988), the slope of the spectral envelope below and above 2.5 kHz (Evers *et al.*, 1998) and relative amplitude (Hedrick and Ohde, 1993). Having more acoustic measurements could allow us to see more acoustic characteristics of fricatives.

The fourth limitation relates to the stimuli of the sound identification and accent rating analyses. In this study, only production from one English word in one vowel context, i.e. /i/ vowel in each fricative was explored. The results of these two analyses thus might not be generalisable to fricatives in all English words or in other vowel contexts. However given that the number of stimuli to be listened by native speakers of English was large (490 stimuli per listener) which took approximately an hour, it would have been time- and energy-consuming to ask them to listen to words in all vowel contexts, and this one word from an /i/ vowel context was a good representative for L2 fricative production as the /i/ vowels of English and Thai are the most similar in terms of articulatory aspects.

The fifth limitation in this study is that this investigation was only on production without perception. SLM proposes that target-like L2 sounds can be produced when L2 learners perceive them as target-like. For example, in the study of Flege *et al.* (1999), their results indicated that Italian speakers of English with early AOA both produced and perceived English vowel as target-like. Although it is not always the case that L2 production is positively correlated with L2 perception, many results in production turn out to be different from what is predicted for L2 production from perception (e.g., Zampini, 1998; Almbark, 2012), the combination of perception and production studies widen the exploration in L2 phonology. However, the analysis of production can be used as a start to future perception study.

The last limitation relates to the sound realisations used for the sound identification task, the accent rating task and acoustic analyses. The sound realisations of the sound identification were randomly selected from one word for high front vowels from the impressionistic analysis regardless of how the sound tokens were realised. In the accent rating, however, the sound realisations were selected only when they were realised as target-like or when they were realised as non-target-like, but were the voiced counterpart of the target-like ones from the impressionistic tokens, and these were also from one word with high front vowels for each fricative. In the acoustic analysis, the sound realisations were only those realised as target-like in the impressionistic analysis. With these different sets of data, the results might not as comparable as assumed. However, the designs of stimuli selection in each analysis do serve the purpose of addressing the research questions.

7.5 Future directions

For future research, four main directions are proposed here. First, the investigation of L2 speech production should be implemented taking into account many types of analysis. In this study, four analyses – impressionistic, sound identification, accent rating and acoustic – were used. The results of each experiment provide insights into aspects of L2 speech production which are to a greater or lesser degree similar to or different from the results of the other experiments. These are pieces of the same picture. Commonly in most previous studies, L2 speech has been investigated using few types of analysis. The flaw of viewing L2 speech production from a small number of aspects is overgeneralisation. For example, as it has been shown in this study, the percentage of target-like production and the scores of sound identification for L2 English /s/ were high, apparently supporting the notion that L2 English /s/ production is due to positive transfer from L1. However, the result from the accent rating task showed that native Thai [s] was perceived as more accented than native English [s] and L2 English [s], signifying that the claim of other researchers on L2 English /s/ produced by Thai learners may be an overgeneralisation. Hence, exploring L2 speech production from several types of analysis strengthens the conclusions derived concerning the characteristics of L2 speech sounds.

The second direction identified for future research is that a model for L2 learners who live in an L2 country for a short period of time (no longer than five years) after years of native language country exposure needs to be built. It is possible that other motivational factors will be important for different groups of learners, driving them to produce L2 non-shared sounds in a native-like manner. Also, this group of L2 learners might be more similar to L2 learners in their home country who use L2 as a foreign language. It would be interesting to investigate further whether these two groups have internal drivers that influence their learning of L2 non-shared sounds.

The third direction is that an investigation of individual differences across speakers should be carried out. As the sample size of L2 Thai learners in this study is large, it is likely that the level of difficulty in producing L2 English fricatives differs across speakers. As the social factors were also explored in this study, it would be interesting to find out if the L2 English production of each speaker was affected by different degrees for these factors.

The last direction identified here is that the investigation of L2 sound production through accent rating and acoustic studies should also be carried out for realisations that are deemed target-like, in addition to combining all realisations into one group. In this study, the analyses of the accent rating task and the acoustic study were carried out only for realisations that were deemed target-like from the impressionistic study, revealing that some of their realisations had high scores for native-likeness and their acoustic characteristics were no different from those of native English production in many contexts. For example, the production of L2 English [v] realisations that were deemed target-like was perceived as native-like and most of the acoustic characteristics were similar to those of native English [v] realisations that were deemed target-like, except for the low vowel context. In this case, although the degree of target-likeness and sound identification for L2 English /v/ was low overall, the accent of realisations that were deemed target-like was perceived as native-like, with acoustic characteristics similar to those of native English [v] in many contexts, suggesting that L2 English [v] realisations that were deemed target-like are produced in a native-like manner.

Appendix A. Questionnaire

Questionnaire

As you agree to participate in this study, you are required to complete the questionnaire to provide personal information and opinions towards English. Your information will be used for Patchanok Kitikanan's research only.

The questionnaire contains 6 pages and is divided into two parts: Personal information and Attitudes towards English. The information you have completed will be confidentially kept, and no individuals will be identifiable in the research.

เนื่องจากท่านได้ตกลงที่จะเข้าร่วมในการศึกษาครั้งนี้ ขอความกรุณาให้ท่านกรอกข้อมูลในแบบสอบถามเพื่อจะให้ข้อมูลส่วนตัวและความคิดเห็นเกี่ยวกับภาษาอังกฤษ ซึ่งข้อมูลของท่านจะถูกใช้ในงานของนางสาวพัทธชนก กิติกานันท์เท่านั้น

แบบสอบถามนี้มี 6 หน้า แบ่งเป็น 2 ส่วนคือ ส่วนข้อมูลส่วนบุคคลและส่วนทัศนคติต่อภาษาอังกฤษ ข้อมูลส่วนนี้จะถูกเก็บเป็นความลับและผู้อ่านจะไม่สามารถระบุผู้เข้าร่วมจากงานวิจัยได้

Part 1: Personal information	*ส่วนที่ 1: ข้อมูลส่วนบุคคล*

1. Name Code (by researcher):___________________________________
   รหัสชื่อ (โดยผู้วิจัย)
2. Age:_____________year
   อายุ ปี
3. Gender:____________________
   เพศ
4. How many months have you been staying in the UK?________ months
   ท่านอยู่ในประเทศอังกฤษมาแล้วทั้งหมด เดือน
5. Languages:____
   ภาษาที่สื่อสารได้
6. First Language:______________________________
   ภาษาที่พูดเป็นภาษาแรก
7. Countries you have stayed (excluding countries for visiting purpose)
   ประเทศที่เคยไปอยู่ (ไม่นับที่เที่ยว):____
8. Average length of English exposure per week:________________hours
   เฉลี่ยรวมระยะเวลาที่ฝึกภาษาอังกฤษต่อสัปดาห์ ชั่วโมง

Part 2: Attitudes towards English *ส่วนที่ 2: ทัศนคติต่อภาษาอังกฤษ*

Directions: Please tick (✓) to choose the option.
คำชี้แจง: กรุณาทำเครื่องหมาย (✓) เพื่อเลือกตอบ

No.	Statement *ประโยค*	Strongly disagree *ไม่เห็นด้วยอย่างยิ่ง*	Disagree *ไม่เห็นด้วย*	Slightly disagree *ไม่เห็นด้วยเล็กน้อย*	Slightly agree *เห็นด้วยเล็กน้อย*	Agree *เห็นด้วย*	Strongly agree *เห็นด้วยอย่างยิ่ง*
1	I can imagine myself speaking English as if I were a native speaker of English. *ฉันสามารถจินตนาการตัวเองตอนพูดภาษาอังกฤษราวกับว่าฉันเป็นเจ้าของภาษาอังกฤษได้*						
2	I study English because close friends of mine think it is important. *ฉันเรียนภาษาอังกฤษเพราะเพื่อนสนิทฉันคิดว่าภาษาอังกฤษสำคัญ*						
3	I would like to spend lots of time studying how to speak English. *ฉันอยากจะใช้เวลามาก ๆ ในการฝึกพูดภาษาอังกฤษ*						
4	I can imagine myself speaking English with international friends or colleagues. *ฉันสามารถจิตนาการตัวเองตอนพูดภาษาอังกฤษกับเพื่อนชาวต่างชาติได้*						
5	If I fail to learn English, I'll be letting other people down. *หากฉันสอบตกในวิชาภาษาอังกฤษ ฉันจะทำให้คนอื่นผิดหวังในตัวฉัน*						
6	I would like to study speaking English even if I were not required. *ฉันอยากฝึกพูดภาษาอังกฤษแม้ว่าจะไม่ใช่วิชาบังคับ*						
7	I can write in English very fast. *ฉันสามารถเขียนเป็นภาษาอังกฤษได้อย่างรวดเร็ว*						
8	Whenever I think of my future career, I imagine myself speaking English. *เมื่อไรก็ตามที่ฉันคิดถึงงานในอนาคต ฉันเห็นภาพตัวเองพูดภาษาอังกฤษ*						
9	I consider learning English important because the people I respect think that I should do it. *ฉันคิดว่าการเรียนภาษาอังกฤษเป็นสิ่งสำคัญเพราะคนที่ฉันนับถือคิดว่าฉันควรจะเรียน*						
10	I would like to concentrate on studying speaking English more than any other topic. *ฉันอยากเน้นฝึกพูดภาษาอังกฤษมากกว่าเรื่องอื่น*						
11	I can imagine myself reading English like a native speaker of English. *ฉันสามารถจินตนาการว่าฉันอ่านภาษาอังกฤษได้เหมือนเจ้าของภาษาอังกฤษ*						

No.	Statement *ประโยค*	Strongly disagree *ไม่เห็นด้วยอย่างยิ่ง*	Disagree *ไม่เห็นด้วย*	Slightly disagree *ไม่เห็นด้วยเล็กน้อย*	Slightly agree *เห็นด้วยเล็กน้อย*	Agree *เห็นด้วย*	Strongly agree *เห็นด้วยอย่างยิ่ง*
12	I can imagine myself speaking English in a university where all my courses are taught in English. *ฉันสามารถจินตนาการตัวเองพูดภาษาอังกฤษในมหาวิทยาลัยที่ทุกวิชาสอนเป็นภาษาอังกฤษ*						
13	Studying English is important to me in order to gain the approval of my peers/teachers/family/boss. *การเรียนภาษาอังกฤษสำคัญสำหรับฉัน เพราะจะทำให้ฉันได้รับการยอมรับจากเพื่อน อาจารย์ ครอบครัว หัวหน้า*						
14	If a speaking English course was offered in the future, I would like to take it. *ถ้ามีวิชาฝึกพูดภาษาอังกฤษให้เลือกเรียนในอนาคต ฉันก็จะเรียน*						
15	I can read in English very fast. *ฉันสามารถอ่านภาษาอังกฤษได้อย่างรวดเร็ว*						
16	I can imagine myself speaking English on the phone fluently. *ฉันสามารถจิตนาการตัวเองตอนคุยโทรศัพท์เป็นภาษาอังกฤษได้อย่างคล่องแคล่ว*						
17	Learning English is necessary because people surrounding me expect me to do so. *การเรียนภาษาอังกฤษเป็นสิ่งจำเป็น เพราะคนรอบข้างต่างคาดหวังให้ฉันเรียน*						
18	If my teacher would give the class an optional chance to speak, I would certainly volunteer to do it. *ถ้าอาจารย์ให้นักเรียนมีโอกาสพูดในห้อง ฉันจะอาสาพูดอย่างแน่นอน*						
19	I can imagine myself writing in English like a native speaker of English. *ฉันสามารถจินตนาการถึงตอนที่ฉันเขียนภาษาอังกฤษได้เหมือนเจ้าของภาษา*						
20	I can imagine myself living abroad and speaking English effectively for communicating with the locals. *ฉันสามารถจินตนาการตัวเองอยู่ต่างประเทศและพูดภาษาอังกฤษเพื่อการสื่อสารกับเจ้าของประเทศได้อย่างมีประสิทธิภาพ*						
21	Studying English is important to me because other people will respect me more if I have the knowledge of English. *การเรียนภาษาอังกฤษสำคัญสำหรับฉันเพราะคนอื่นจะนับถือในตัวฉันมากขึ้นหากฉันมีความรู้ด้านภาษาอังกฤษ*						
22	I am prepared to expend a lot of effort in learning how to improve English pronunciation. *ฉันเตรียมพร้อมที่จะใช้ความพยายามอย่างเต็มที่เพื่อเรียนรู้วิธีการปรับปรุงการออกเสียงภาษาอังกฤษ*						

No.	Question *คำถาม*	Not at all *ไม่เลย*	Not so much *ไม่มาก*	So-so *เฉย ๆ*	A little *เล็กน้อย*	Quite a lot *ค่อนข้างมาก*	Very much *มาก*
23	Do you like the atmosphere of your English classes? *คุณชอบบรรยากาศห้องเรียนภาษาอังกฤษหรือไม่*						
24	How tense would you get if a foreigner asked you for directions in English? *คุณกังวลแค่ไหน ถ้ามีชาวต่างชาติมาถามทางคุณเป็นภาษาอังกฤษ*						
25	How bad do you think your writing is? *คุณคิดว่าการเขียนของคุณแย่แค่ไหน*						
26	Do you find learning English really interesting? *คุณพบว่าการเรียนภาษาอังกฤษน่าสนใจจริง ๆ หรือไม่*						
27	How uneasy would you feel speaking English with a native speaker? *คุณรู้สึกอึดอัดแค่ไหน ถ้าต้องพูดภาษาอังกฤษกับเจ้าของภาษา*						
28	How bad to you think your reading is? *คุณคิดว่าการอ่านของคุณแย่แค่ไหน*						
29	Do you think time passes faster while studying English? *คุณคิดว่าเวลาผ่านไปเร็วขึ้นเมื่อคุณเรียนภาษาอังกฤษหรือไม่*						
30	How nervous and confused do you get when you are speaking in your English class? *คุณกังวลและสับสนแค่ไหน เมื่อต้องพูดภาษาอังกฤษในชั้นเรียน*						
31	Do you always look forward to English classes? *คุณจะตั้งหน้าตั้งตารอคอยให้ถึงวิชาเรียนภาษาอังกฤษหรือไม่*						
32	How afraid are you of sounding stupid in English because of the mistakes in speaking you make? *คุณกลัวแค่ไหน ที่จะฟังดูโง่เพราะพูดผิด*						
33	Would you like to have more English lessons at school? *คุณอยากจะให้มีวิชาภาษาอังกฤษมากกว่านี้ในโรงเรียนหรือไม่*						
34	How worried are you that other speakers of English would find your English accent strange? *คุณกังวลแค่ไหน หากคนที่พูดภาษาอังกฤษคนอื่น ๆ คิดว่าสำเนียงคุณแปลก*						
35	Do you really enjoy learning English? *คุณสนุกกับการเรียนภาษาอังกฤษอย่างแท้จริงหรือไม่*						
36	How afraid are you that other students will laugh at you when you speak English? *คุณกลัวแค่ไหน ว่าคนอื่นจะหัวเราะคุณเมื่อคุณพูดภาษาอังกฤษ*						

End of the Questionnaire.

สิ้นสุดแบบสอบถาม

Thank you for your time.

ขอขอบพระคุณสำหรับเวลาของท่าน

Appendix B. Consent form for sound production task for Thai speakers

Consent Form

NEWCASTLE UNIVERSITY

You have been invited to participate in a research project by Patchanok Kitikanan conducting a thesis on English acquisition by Thai learners at Newcastle University. Your participation in this project is entirely voluntary.

If you agree to participate, your participation will consist of reading words in Thai and English and listen to non-sense words. Each task is done separately, and the entire session should take about 1.30 hours.

AGREEMENT

I agree that the study and recording of my assessment and accompanying material be:

1. Made available to Patchanok Kitikanan's research.
   Quoted in published work or used in public performance in full or in part.
2. Used for teaching purposes.

Name of Participant: ______________________________

Signature of Participant: ______________________________

Date of Signature: ______________________________

Appendix C. Consent form for sound production task for British speakers

Consent Form

NEWCASTLE UNIVERSITY

You have been invited to participate in a research project by Patchanok Kitikanan conducting a thesis on English acquisition by Thai learners at Newcastle University. Your participation in this project is entirely voluntary.

If you agree to participate, your participation will consist of reading words in English and non-sense words. You will read all words three times. The entire session should take about 30 hours.

AGREEMENT

I agree that the study and recording of my assessment and accompanying material be:

1. Made available to Patchanok Kitikanan's research.
   Quoted in published work or used in public performance in full or in part.
2. Used for teaching purposes.

Name of Participant: ______________________________

Signature of Participant: ______________________________

Date of Signature: ______________________________

Appendix D. Consent form for sound identification task

Consent Form

NEWCASTLE UNIVERSITY

You have been invited to participate in a research project which is being carried out by Patchanok Kitikanan, a PhD student in Phonetics and Phonology at Newcastle University. Patchanok is carrying out a study on the acquisition of English by Thai learners. Your participation in this project is entirely voluntary.

If you agree to participate, you will be listening to the first part of isolated words as produced by a variety of native and non-native speakers and you will be asked to identify the words that you hear from a list of alternatives. The entire session should take no longer than 1 hour and you will be given breaks for every 100 stimuli. Your participation would be highly appreciated and you would be contributing to better understanding of phonetic factors that contribute to the foreign accent perception of speech.

AGREEMENT

I agree that my responses will be:

1. Made available to Patchanok Kitikanan's research.
   Quoted in published work or used in public performance in full or in part.
2. Used for teaching purposes.

Name of Participant: ______________________________

Signature of Participant: ______________________________

Date: ______________________________

Please also answer the following questions:

1) Where is your birthplace? ______________________________

2) Where have you lived for most of your life? ______________________________

3) How old are you? ______________________________

4) What is your programme of study? ______________________________

5) What year are you in? ______________________________

6) Do you have some background knowledge of Thai?

____

7) Are you familiar with Thai-accented English?

____

8) How many languages can you speak?

____

9) Do you have any history of speech and/or language disorders (including hearing impairment)? (if yes please provide details) ______________________________

Appendix E. Consent form for accent rating task

Consent Form

NEWCASTLE UNIVERSITY

You have been invited to participate in a research project which is being carried out by Patchanok Kitikanan, a PhD student in Phonetics and Phonology at Newcastle University. Patchanok is carrying out a study on the acquisition of English by Thai learners. Your participation in this project is entirely voluntary.

If you agree to participate, you will be listening to the first part of isolated words as produced by a variety of native and non-native speakers and you will be asked to rate the accentness of each stimulus on a scale of 1 to 9. The entire session should take about 1 hour but you will be given breaks for every 100 stimuli. Your participation would be highly appreciated and you would be contributing to better understanding of phonetic factors that contribute to the perception of speech as foreign accented.

AGREEMENT

I agree that my responses will be:

1. Made available to Patchanok Kitikanan's research.
   Quoted in published work or used in public performance in full or in part.
2. Used for teaching purposes.

Name of Participant: ______________________________

Signature of Participant: ______________________________

Date: ______________________________

Please also answer the following questions:

1) Where is your birthplace? ______________________________

2) Where have you lived for most of your life? ______________________________

3) How old are you? ______________________________

4) What is your programme of study? ______________________________

5) What year are you in? ______________________________

6) Do you have some background knowledge of Thai?

____

7) Are you familiar with Thai-accented English?

____

8) How many languages you can speak?

____

9) Do you have any history of speech and/or language disorders (including hearing impairment)? (if yes please provide details) ______________________________

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