EPENTHETIC VOWELS IN ENGLISH LOANWORDS IN KOREAN: A PHONETIC AND PERCEPTUAL ANALYSIS

by

HYUNJIN LEE

(Under the Direction of Margaret E. L. Renwick)

ABSTRACT

Vowel epenthesis is an essential strategy in the adaptation of English loanwords into Korean. Despite its importance, epenthetic vowels remain relatively underexplored across diverse linguistic contexts. This dissertation therefore investigates epenthetic vowels in both production and perception to deepen our understanding of how these processes contribute to the patterns of vowel epenthesis observed in Korean loanword adaptation.

In production, the study explores how bilingualism and speech rate affect the phonetic features of epenthetic and lexical vowels. Results show that Korean monolinguals produce epenthetic and lexical vowels with similar F1, F2, and duration. However, Korean-English bilinguals produce epenthetic vowels with a higher F2 than lexical vowels, due to the influence of English [ɨ]. Bilinguals may apply L2 sounds to L1 loanword adaptation (Kadenge & Mudzingwa 2012; Zellou 2011), suggesting that English [ɨ] with higher F2 may replace Korean /ɨ/ in the Korean speech of bilinguals. The study also compares vowel production at normal and fast speech rates. At each rate, epenthetic and lexical vowels exhibit similar phonetic features. However, while both epenthetic and lexical /i/ show centralization at faster speech rates,

epenthetic and lexical /ɨ/ do not. This may relate to vocal tract inertia (Jaworski 2009), where peripheral vowels like /i/ are more affected than central vowels like /ɨ/.

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DEDICATION

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CHAPTER 1

INTRODUCTION

1.1 English loanword adaptation in Korean

Loanword adaptation from English to Korean involves phonological and phonetic changes such as epenthesis, where vowels are inserted; elision, which involves the deletion of certain sounds; and feature changes, wherein specific phonetic properties of segments are modified. For example, English *hard* has been adapted as [hɑtɨ] in Korean. As shown in this loanword, English /ɹ/ is omitted, English /d/ changed into [t], and /ɨ/ is inserted at the end of the word. These changes are generally caused by the different phoneme inventories and phonotactics between English and Korean. Specifically, Korean does not allow any consonant clusters in syllables, so phonological changes must occur to repair these clusters in two different ways. In Korean, English /ɹ/ immediately following a vowel is generally omitted (Kim 2008); therefore, if a consonant cluster includes a postvocalic /ɹ/, it is deleted. If not, vowel epenthesis is applied to break up the consonant cluster in English loanwords. Vowel epenthesis is also used in Korean to avoid simple illicit codas, as only seven consonants [p], [t], [k], [n], [m], [ŋ], and [l] are permitted in coda position. However, in cases such as the English loanword [hɑtɨ], /ɨ/ epenthesis often occurs even after a licit coda in Korean. This represents an instance of unnecessary epenthesis and suggests that vowel epenthesis in Korean cannot be fully explained by focusing solely on Korean phonological grammar.

As seen in English *hard*, where English /d/ is adapted as Korean [t], the differences between the English and Korean phoneme inventories cause sound changes in English loanwords in Korean. Korean has 10 monophthongs, 11 diphthongs, and 19 consonants, as shown in the following tables. All vowel and consonant inventories were created based on the regulation of the standard language (Ministry of Culture, Sports and Tourism 2017).

Table 1.1 Korean consonant inventory

		Bilabial	Alveolar	Alveolo-palatal	Velar	Glottal
Plosive	Plain	p	t		k	
	Aspirated	p^h	t^h		k^h	
	Tense	p’	t’		k’	
Affricate	Plain			ʧ		
	Aspirated			$ʧ^h$		
	Tense			ʧ’		
Fricative	Plain		s			h
	Fortis		s’			
Nasal		m	n		ŋ	
Lateral approximant			l			

Table 1.2 Korean monophthong inventory[1]

	Front		Back	
	Unrounded	Rounded	Unrounded	Rounded
High	i	y	ɨ	u
Mid	ɛ	ø	ʌ	o
Low	æ		ɑ	

Table 1.3 Korean diphthong inventory

	ɑ	ʌ	o	u	ɛ	æ	ɨ
j	jɑ	jʌ	jo	ju	jɛ		ɨj
w	wa	wʌ			wɛ		

As presented in Table 1.1, Korean does not have a consonant voicing contrast. Instead, it has three types of consonants: plain, aspirated, and tense. However, intervocalic Korean plain consonants /p/, /t/, /k/, and /ʧ/ are voiced.

Generally, English voiced consonants are adapted as plain Korean consonants, and voiceless ones are adapted as aspirated consonants in English loanwords in Korean. Since Korean has fewer consonants compared to English, English consonants which do not exist in Korean have been adapted with some phonetic changes. For example, English /f/ and /v/ do not exist in the Korean consonant

[1] According to the regulation of the standard language (Ministry of Culture, Sports and Tourism 2017), Korean has 10 monophthongs, as shown in Table 1.2. However, many Korean linguists argue that /ɛ/ and /æ/ have merged into /ɛ/ and that both /y/ and /ø/ should be considered diphthongs in Korean (Heo 2004; Shin 2016).

inventory, so they are adapted as /pʰ/ and /p/, respectively. In the case of vowels, Korean does not have tense and lax distinctions. Thus, both English tense and lax vowels are adapted as the same vowel in Korean (e.g., English tense /i/ and lax /ɪ/ are both adapted as Korean /i/).

While /ɨ/ is a central vowel in many languages such as English (Flemming & Johnson 2007; Trager & Bloch, 1941), Romanian (Renwick 2012), and Russian (Yanushevskaya & Bunčić 2015), it is phonologically defined as a back vowel in Korean, as shown in Table 1.2. However, many studies argue that /ɨ/ is phonetically classified as a central vowel with slight tongue retraction (Lee & Ramsey 2011; Umeda 2022). Given that the production of vowels is one of the key focuses of this dissertation, /ɨ/ will be classified as a central vowel with slight tongue retraction in this study.

1.2 Production of epenthetic vowels

Cross-linguistically, words borrowed from a source language frequently undergo phonological modifications to align with the phonology of the recipient language. A common phonological modification in loanword adaptation is vowel epenthesis, a repair strategy that transforms illicit non-native inputs into permissible native outputs (Hall 2011; Pulleyblank 1998; Uffmann 2006). Specifically, vowel epenthesis commonly serves to repair illicit consonant clusters and/or to prevent simple illicit codas in the recipient language (Hall 2011; Kang 2003; Uffmann 2006). Korean presents a clear example of both phenomena in the adaptation of English loanwords. Korean prohibits consonant clusters, so epenthetic /ɨ/ is used to break up the clusters found in English words (e.g., *spa* [sɨpʰɑ], *hamstring* [hæmsɨtʰɨliŋ]). Furthermore, since Korean restricts the coda position to only seven consonants [p], [t], [k], [n], [m], [ŋ], and [l], /ɨ/ epenthesis functions to prevent other consonants from occupying this position (e.g., *beet* [pitʰɨ], *cake* [kʰeikʰɨ]). For this purpose, /i/ epenthesis also occurs, but only after English post-alveolar consonants /ʒ/, /ʃ/, /ʤ/, or /ʧ/ (e.g., *fish* [pʰisi], *large* [lɑʧi]).

In many languages, epenthetic vowels and their corresponding lexical vowels have different phonetic features (Bellik 2019; Davidson 2006; Gouskova & Hall 2009, Hall 2013; Miner 1979). For instance, Davidson (2006) argues that native English speakers often insert an epenthetic schwa to repair illicit consonant clusters. This epenthetic schwa is characterized by a shorter duration and lower first and second formant values (F1 and F2) compared to a lexical schwa. In addition, Gouskova and Hall (2009) show that epenthetic /i/ is significantly shorter in duration than lexical /i/ in Lebanese Arabic. On the other hand, in Korean, there are no phonetic differences between them. For example, Kim (2009) and Kim and Kochetov (2011) found that these two types of vowels exhibited the similar F1 and F2 formant values and vowel durations in sentence-level read speech.

Variations in speech rate can influence the phonetic characteristics of vowels. Previous studies report that vowel centralization at the fast speech rate has been observed in different languages such as English (Agwuele et al. 2008; Miller 1981; Turner et al. 1995), Spanish (Nadeu 2014), and Korean (Igeta et al. 2017; Lee et al. 2002). Also, vowels within the same language can exhibit different changes depending on speech rate. For instance, Hirata and Tsukada (2003) examined the F1 and F2 formants values of five short Japanese vowels /i, e, a, o, u/ and their long counterparts /iː, eː, aː, oː, uː/ across slow and fast speech rates. They found that speech rate has a greater impact on the short mid vowels /e/ and /o/ compared to other vowels. In addition, the vowel durations may change depending on speech rate (Gay 1978; Magen & Blumstein 1993; Smith 2002). Cross-linguistically, it becomes shorter at the fast speech rate than at slow or normal speech rates. For instance, eight Korean lexical vowels /i, e, ɛ, ə, u, ɨ, o, ɑ/ are shorter at the fast speech rate than at the slow speech rate (Magen & Blumstein 1993). Also, Gay (1978) observed that as speech rate increases, the duration of stressed vowels in English becomes shorter.

In Korean, very few studies investigate the phonetic features of lexical vowels at different speech rates. For example, Lee et al. (2002) argue that although vowel durations of lexical /ɑ, i, u, æ, o, ʌ, ɨ/ become shorter at the fast speech rate, there were no differences in F1 and F2 values across slow, normal, and fast speech rates. In contrast, Son (2017) investigated Korean lexical vowels /ɑ, i, u, æ, ɛ, o, ʌ, ɨ/ and found that the formant values of /ɑ, i, u, ɛ, o/ changed as speech rate increased with varying degrees of change. Igeta et al. (2017) focused on Korean back vowels /u, o/ and found that they became centralized as speech rate increased. However, these studies have certain limitations. In Lee et al. (2002) and Igeta et al. (2017), data were collected from a limited number of native Korean speakers using standard Korean: specifically, two female and two male speakers in Lee et al. (2002) and six female and six male speakers in Igeta et al. (2017). Son (2017) included thirty-two female participants, but participants spoke different regional dialects. As a result, these findings might be limited by the restricted number of participants or potential dialectal variations that could have influenced the outcomes.

In the case of Korean epenthetic vowels, there is a lack of research examining the phonetic features of Korean epenthetic vowels at different speech rates. Moreover, there appears to be no research comparing epenthetic vowels and the corresponding lexical vowels at different speech rates in Korean. However, speech rate may affect them in different ways. First, the occurrence of epenthetic vowels can vary depending on speech rate, unlike lexical vowels. For example, Tajima et al. (2002) found that epenthetic vowels can disappear at faster speech rates in Japanese-accented English. Second, speech rate can either eliminate or enhance differences in the phonetic features of epenthetic and lexical vowels. For instance, Gouskova and Hall (2009) observed that lexical vowels are longer than epenthetic vowels at slower speech rates in Lebanese Arabic. However, this durational difference disappears at faster speech rates (Hall 2013). Conversely, speech rate can also cause distinctions between epenthetic and lexical vowels. According to Bellik (2019), while Turkish lexical vowels tend to shorten in casual, fast speech compared to careful speech, non-lexical vowels remain unchanged because they are already reduced to the minimal duration permitted by Turkish gestural timing. Thus, it is worthwhile to examine whether the phonetic features of epenthetic and lexical vowels exhibit similar or divergent patterns across varying speech rate in Korean, as epenthetic and lexical vowels at different speech rates remain largely unexplored.

Since previous studies (Kim 2009; Kim & Kochetov 2011; Shin & Iverson 2014) found no phonetic differences between epenthetic vowels and corresponding lexical vowels in sentence-level read speech, the studies in this dissertation are expected to yield similar results during read speech at the normal speech rate. Specifically, epenthetic /ɨ/ and /i/ are anticipated to have the same F1, F2, and duration values as their respective lexical counterparts, /ɨ/ and /i/ at the normal speech rate. On the other hand, in the case of the fast speech rate, the F2 value of epenthetic /ɨ/ can be more centralized compared to that of lexical /ɨ/. According to Oh (1992), while epenthetic /ɨ/ is specified for [+high], it lacks a target backness articulation for the F2 formant value. If the target articulation is not specified, the articulation tends to be centralized (Bender 1968; Choi 1992; Flemming 2004; Vaux & Samuels 2015). Thus, the F2 value of epenthetic /ɨ/ is possibly more centralized than that of lexical /ɨ/ at the fast speech rate, where phonetic reduction such as undershoot is more prominent (Greenberg 1999; Tucker & Mukai 2023; Warner & Tucker 2011).

My previous research (2022) on the phonetic differences between epenthetic /ɨ/ and lexical /ɨ/ in a corpus of Korean broadcast speech found that (a) epenthetic /ɨ/ and lexical /ɨ/ have similar duration, (b) they share similar F1 formant values, but (c) they differ in F2 formant values, with epenthetic /ɨ/ having a higher F2 value. One possible reason for the higher F2 of epenthetic /ɨ/ is the English fluency and experience of Korean speakers in in the corpus. The corpus did not provide any information about the speakers' language backgrounds. However, given that the recordings were produced and aired in the Washington, D.C. area in the U.S., it can be reasonably assumed that the speakers are Korean-English bilinguals or, at the very least, proficient in English. If this is the case, it is possible that these speakers produce English [ɨ] rather than Korean /ɨ/ in English loanwords. In English, the F1 formant value of [ɨ] (e.g., *roses* [ɹoʊzɨz]) is around 400 Hz (Flemming & Johnson 2007), like Korean lexical /ɨ/. However, its F2 formant value is between 1900 and 2000 Hz (Flemming & Johnson 2007), much higher than 1500 Hz which is the average F2 formant value of Korean lexical /ɨ/. This may be attributed to the different phonetic characteristics between the English [ɨ] and the Korean lexical /ɨ/. In Korean, /ɨ/ is a central vowel with slight tongue retraction, whereas in English, it is simply a central vowel. Thus, the Korean lexical /ɨ/ has a lower F2 than the English one.

Previous studies (Kadenge & Mudzingwa 2012; Zellou 2011) demonstrate that bilinguals apply L2 phonology to loanwords in their L1. Therefore, it is possible that the Korean speakers in the previous study (2022) used the English [ɨ] instead of the Korean lexical /ɨ/ in English loanwords. To discern whether the difference in F2 between epenthetic /ɨ/ and lexical /ɨ/ is caused by exposure to L2 English, this study analyzes comparable read speech produced by Korean monolinguals. If epenthetic /ɨ/ and lexical /ɨ/ produced by Korean monolinguals have similar phonetic characteristics, the higher F2 observed in the previous study (2022) may be a result of bilingualism.

1.3 Perception of epenthetic vowels

Vowel epenthesis in English loanwords in Korean arises primarily for two reasons: to break consonant clusters and to avoid disallowed simple consonants in coda positions. This explanation, grounded in syllable structure constraints, effectively accounts for many instances of vowel epenthesis in English loanwords in Korean but also has certain limitations. For example, it does not clarify why Korean lexical words and English loanwords handle coda clusters differently. The native Korean word /sɑks/ 'wage' is pronounced [sɑk] with /s/-deletion, whereas the English loanword *socks* is realized as [sɑksɨ] with /ɨ/ epenthesis. Despite the two words being near-minimal pairs, /ɨ/ epenthesis appears only in the loanword. Additionally, /ɨ/ epenthesis sometimes occurs where it seems unnecessary. For instance, the English word *hood* becomes [hutɨ] in Korean, even though the English consonant /d/ (realized as /t/ in Korean) is permissible in Korean coda positions. These examples suggest that syllable structure restrictions alone cannot fully explain vowel epenthesis in Korean.

Perceptual studies propose an alternative perspective by emphasizing how native listeners perceive non-native sounds. Perceptual research (Kenstowicz 2003; Peperkamp & Dupoux 2003; Silverman 1992) indicates that loanword adaptations reflect the perceived similarity between a source language and a recipient language. Similarly, perceptual studies on /ɨ/ epenthesis in Korean (Kang 2003; Kim 2008; Kim 2021, 2022) found that native Korean listeners perceive English forms in certain linguistic contexts as more similar to Korean forms with /ɨ/ epenthesis than without it. These studies argue that the perceptual similarity plays a key role in the occurrence of /ɨ/ epenthesis during the adaptation of English loanwords into Korean.

Korean has two epenthetic vowels /ɨ/ and /i/ which behave differently. Epenthetic /i/ consistently appears in specific environments within English Consonant-Vowel-Consonant (CVC) monosyllabic structures ending in English post-alveolar consonants /ʒ/, /ʃ/, /ʤ/, or /ʧ/ to repair illicit simple codas. Epenthetic /ɨ/ is also used to avoid illicit simple codas and to break up the consonant clusters in English CVC monosyllabic structures. However, unlike /i/ epenthesis, the occurrence of /ɨ/ epenthesis in these structures varies depending on the linguistic context. For example, /ɨ/ epenthesis never occurs in English CVC forms ending in an English sonorant (i.e., a liquid or a nasal) and must occur in forms ending in one of the following English fricatives: /f/, /v/, /θ/, /ð/, /s/, and /z/. However, in English CVC forms ending in an English stop consonant, /ɨ/ epenthesis may or may not occur, prompting extensive discussion about the linguistic factors that influence its likelihood. Hence, this study focuses on vowel epenthesis at the end of English CVC monosyllabic structures for the following reasons: (a) epenthetic /ɨ/ always occurs between consonants to break up clusters, regardless of the linguistic environment, but its occurrence at the end of CVC structures may vary depending on the context, (b) word length can influence the perception of /ɨ/ epenthesis (Kim 2022), and (c) epenthetic /i/ occurs exclusively at the end of CVC structures. Thus, this study examines vowel epenthesis in English CVC monosyllabic structures.

As mentioned briefly above, there are phonological patterns in English CVC monosyllabic structures in English loanword adaptations in Korean: (a) /ɨ/ epenthesis never occurs in English CVC monosyllabic structures ending in a sonorant, and (b) it always occurs in those ending in a fricative. These patterns are consistent and do not exhibit any exceptions in English loanword adaptations in Korean.

However, even though these patterns apply consistently, it does not mean that native Korean listeners always perceive /ɨ/ epenthesis after a fricative or never perceive it after a sonorant. For instance, according to Kim (2008), while most native Korean speakers adhered to these two phonological patterns perceptually, there were instances where some speakers perceived /ɨ/ epenthesis after a sonorant and no /ɨ/ epenthesis after a fricative. In addition, /ɨ/ epenthesis rates after a sonorant or a fricative are also influenced by phonetic environments such as voicing and release of the final stop in English CVC monosyllabic structures. This indicates that although the general patterns are robust, variations can still occur among native Korean listeners. Similar to English CVC forms ending in a sonorant or a fricative, there is a phonological pattern for /i/ epenthesis: it must always occur after English post-alveolar consonants /ʒ/, /ʃ/, /ʤ/, or /ʧ/. As it is a consistent rule without exceptions, there has been limited research on the perception of /i/ epenthesis. Therefore, this study aims to investigate the perceptual patterns of both /ɨ/ and /i/ epenthesis, examining how native Korean listeners perceive them across different linguistic factors and identifying any previously unrecognized patterns in their occurrence.

Well-known linguistic factors influencing /ɨ/ epenthesis in English CVC monosyllabic structures include the voicing, release, and place of articulation of the final stop and the tenseness of the pre-final vowel (Kang 2003; Kim 2008; Kim 2021; Kwon 2017). In this context, the final stop refers to the last consonant in the English CVC monosyllabic structure, and the pre-final vowel refers to the sole vowel in that structure. For example, in English /pit/, /t/ is the final stop, and /i/ is the pre-final vowel. This study explores the impact of individual factors including the release, voicing, place of articulation of the final consonant, and the tenseness of the pre-final vowel. It also examines the interactions between these factors. In addition, the English proficiency of native Korean listeners is considered a factor in the perception of /ɨ/ epenthesis. Specifically, this study investigates the relationship between native Korean listeners' ability to discriminate English tense and lax vowels and the perceived occurrence of /ɨ/ epenthesis when the pre-final vowel is tense.

Unlike /ɨ/ epenthesis, there are no well-established linguistic factors that perceptually influence the occurrence of /i/ epenthesis. Therefore, similar linguistic factors considered for /ɨ/ epenthesis are also examined in the context of /i/ epenthesis. Since /i/ epenthesis occurs after English post-alveolar consonants (/ʒ/, /ʃ/, /ʤ/, and /ʧ/), the voicing of the final consonant can be investigated as a potential factor. In addition, the tenseness of the pre-final vowel and the ability to discriminate the English tense/lax contrast are examined as possible factors. However, the place of articulation of the final consonant cannot be considered a factor, as /i/ epenthesis only occurs after English post-alveolar consonants. In addition, since these consonants cannot be unreleased, the release of the final consonant is also not a relevant factor. Instead, the noise duration of the final consonant will be investigated. Given that final sibilants are more likely to be perceived with an epenthetic vowel than non-sibilants due to their salient consonant noise (de Jong & Park 2012), a longer noise duration may lead native Korean listeners to perceive epenthetic /i/ more frequently than when the sibilants are produced with a shorter noise duration.

By investigating /ɨ/ and /i/ epenthesis with respect to various linguistic factors, this study aims to explore potential parallels and divergences in how native Korean listeners perceive these epenthetic vowels. In doing so, it may contribute to a better understanding of the overall vowel epenthesis processes involved in English loanword adaptation in Korean.

1.4 Dissertation structure

Chapter 2 reviews the previous studies on the production and perception of vowel epenthesis in English loanwords in Korean, laying the groundwork for the experimental analysis of vowel epenthesis in the following chapters. First, the chapter examines how vowel epenthesis repairs illicit English consonant clusters and prevents illicit coda structures to conform to Korean phonotactics. It also explains the conditions under which epenthetic /i/ or /ɨ/ is used depending on the preceding consonant. Next, this chapter introduces the production of vowel epenthesis by comparing Korean with other languages such as

Ho-Chunk (Hall & Sue 2018; Susman 1943) and Lebanese Arabic (Gouskova & Hall 2009; Hall 2013), where epenthetic vowels differ phonetically from the corresponding lexical vowels. These studies argue that epenthetic vowels are often shorter in duration and more centralized, and these characteristics may reflect incomplete neutralization during adaptation. Also, the chapter addresses factors such as speech rate and bilingualism that influence the production of epenthetic vowels. The fast speech rate may lead to more centralization, and bilingual speakers may produce epenthetic vowels reflecting the phonetics of the source language.

Next, this chapter introduces general perceptual perspectives on vowel epenthesis (Broselow 2003; Kenstowicz 2003) and explains how experience with the source language can influence loanword adaptation (Best & Tyler 2007; Boersma & Hamann 2009; Chang 2008; Wang 2023). These experimental studies form the basis of the hypothesis that Korean speakers' ability to distinguish between tense and lax vowels in English may affect the occurrence of perceived /ɨ/ epenthesis.

Chapter 3 investigates whether epenthetic vowels in Korean have phonetic differences from the corresponding lexical vowels based on two factors: speech rate and bilingualism. First, cross-linguistic evidence shows that different speech rates can result in different phonetic features of vowels, with the fast speech rate generally resulting in vowel centralization and reduced duration (Agwuele et al. 2008; Miller 1981; Nadeu 2014; Turner et al. 1995). However, previous research on Korean epenthetic and lexical vowels at different speech rates seems to be limited. Therefore, this chapter thoroughly explores the phonetic characteristics of epenthetic and lexical vowels at both normal and fast speech rates. Importantly, this study hypothesizes that while epenthetic and lexical vowels may be similar at the normal speech rate, the fast rate may lead to greater centralization of epenthetic /ɨ/ due to underspecified articulatory target for epenthetic /ɨ/ (Oh 1992). This hypothesis builds on two arguments: (a) underspecified vowels tend to be centralized (Bender 1968; Choi 1992; Flemming 2004) and (b) the fast speech rate amplifies phonetic reduction such as undershoot (Tucker & Mukai 2023; Warner & Tucker 2011).

Next, this chapter introduces preliminary findings from my prior research (2022) suggesting that L2 influence may contribute to higher F2 formant values in epenthetic /ɨ/ among Korean-English bilinguals during read speech. To verify this assumption, it is necessary to use Korean monolinguals as a control group without L2 influence, so this dissertation examines read speech produced by monolingual Korean speakers.

Chapter 4 investigates the perceptual patterns of vowel epenthesis in English loanwords in Korean with a particular focus on English CVC monosyllabic structures. The chapter explores the occurrence of two epenthetic vowels /ɨ/ and /i/ and examines the linguistic factors influencing native Korean listeners' perception of these epenthetic vowels. The study analyzes how factors such as the voicing and release of the final consonant impact perceived vowel epenthesis rates. Also, this chapter considers the role of individual differences in native Korean listeners' ability to discriminate between English tense and lax vowels. By applying these factors to both /ɨ/ and /i/ epenthesis, this chapter seeks to identify parallels and divergences in the perceptual patterns of /ɨ/ and /i/ epenthesis in the adaptation of English loanwords in Korean.

Chapter 5 discusses the results from Chapters 3 and 4, and Chapter 6 summarizes the main findings on the production and perception of vowel epenthesis in Korean. The results on production suggest that native Korean speakers produce epenthetic vowels as full phonetic units rather than transitional sounds. On the perceptual side, the ability to distinguish between English tense and lax vowels plays a significant role in the perception of /ɨ/ epenthesis. Native Korean listeners with stronger vowel discrimination skills are more likely to perceive /ɨ/ when the pre-final vowel is tense. These findings highlight not only the importance of perceptual factors but also the influence of experience with the source language on loanword adaptations in Korean.

CHAPTER 2

LITERATURE REVIEW

2.1 Epenthetic vowels in English loanwords in Korean

Until the mid-1980s, Korean had three epenthetic vowels: /i/, /u/, and /ɨ/, which were used in specific environments depending on the place of articulation of the preceding consonant (Kim & Kochetov 2011; Oh 1992). First, epenthetic /i/ occurred after English post-alveolar consonants /ʒ/, /ʃ/, /ʤ/, or /ʧ/, as in *mirage* [milɑʧi] and *fish* [pʰisi]. Next, epenthetic /u/ occurred after English labial consonants (/b/ and /p/) or fricative consonants (/f/ and /v/), as in *lamp* [læmpʰu] and *knife* [nɑipʰu]. Epenthetic /ɨ/ was also used after English labial consonants, as in *lamp* [læmpʰɨ] and *knife* [nɑipʰɨ] and in all other environments. Thus, epenthetic /ɨ/ and /u/ were interchangeable after English labial consonants in English loanwords in Korean.

In 1986, the regulation of loanword orthography was established by the Ministry of Education in Korea and has been revised multiple times, with the most recent version being from 2017. According to this regulation, both English voiceless stops /p/, /t/, and /k/ and voiced stops /b/, /d/, and /g/ are accompanied by epenthetic /ɨ/ in coda positions in Korean. This rule also affected English fricative consonants /f/ and /v/. Since Korean lacks fricatives, /f/ and /v/ were introduced as Korean labials /pʰ/ and /p/, respectively. As a result, epenthetic /u/ after English labial or fricative consonants was no longer used in English loanwords in Korean. Instead, epenthetic /ɨ/ began to be exclusively used in these environments.

Cross-linguistically, vowel epenthesis serves to repair illicit consonant clusters and/or to prevent illicit codas in the loanword process (Hall 2011; Kang 2003; Uffmann 2006), and Korean also uses vowel epenthesis for the same purposes.

(2.1) Illicit consonant clusters

spring	[sɨpʰɨliŋ]
steam	[sɨtʰim]
crumble	[kʰɨlʌmpɨl]

(2.2) Simple illicit codas

peak	[pʰikʰɨ]
meat	[mitʰɨ]
soup	[supʰɨ]
coach	[kʰoʧʰi]
judge	[ʧʌʧi]
fish	[pʰisi]

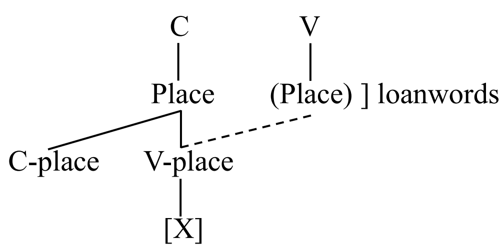
(2.3) Illicit consonant clusters and simple illicit codas

mask	[mɑsɨkʰɨ]
host	[hosɨtʰɨ]

Since Korean prohibits all types of consonant clusters within syllables, vowel epenthesis is used to break up English consonant clusters. In this case, only epenthetic /ɨ/ can be used for this purpose. In (2.1), epenthetic /ɨ/ changes English consonant clusters into simple consonants in Korean. Also, as shown in *spring* in (2.1), epenthetic vowels can appear multiple times to break up one consonant cluster. Next, (2.2) presents vowel epenthesis for a different purpose. In Korean, only seven sounds [p], [t], [k], [n], [m], [ŋ], and [l] are permitted in coda position. Therefore, epenthetic /ɨ/ is used to prevent illicit codas from occupying this position. After vowel epenthesis occurs, the previously illicit coda consonant becomes the onset of the following syllable. In this case, both epenthetic /ɨ/ and /i/ can be used depending on the preceding consonant. If it is an English post-alveolar, epenthetic /i/ must be used such as *coach* [kʰoʧʰi]; otherwise, epenthetic /ɨ/ is used such as *peak* [pʰikʰɨ]. In (2.3), vowel epenthesis can occur for both purposes. For example, in *mask*, vowel epenthesis between English /s/ and /k/ occurs to break up the consonant cluster /sk/, and another epenthetic vowel appears after English /k/ to prevent the illicit coda in Korean.

While both epenthetic /ɨ/ and /i/ function as a repair strategy to change illicit English inputs into licit Korean outputs, they have the different characteristics. Specifically, Oh (1992) argues that epenthetic /ɨ/ serves as the default epenthetic vowel and is more underspecified than both epenthetic /i/ and /u/.[2] To support this argument, she suggests the assimilation structure (Oh 1992:157) between the preceding consonant and following epenthetic vowel in English loanwords in Korean.

(2.4) Assimilation

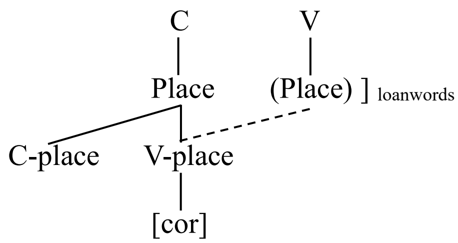


In (2.4), a consonant has both a consonant place (C-place) and a vowel place (V-place) node, and its V-place node spreads to the following epenthetic vowel. In other words, the underspecified epenthetic vowel may be realized differently depending on the V-place node of the preceding consonant. If the preceding consonant is palatal[3], its V-place has [coronal] feature. If the preceding consonant is labial, it has [labial] feature as shown in (2.5) and (2.6).

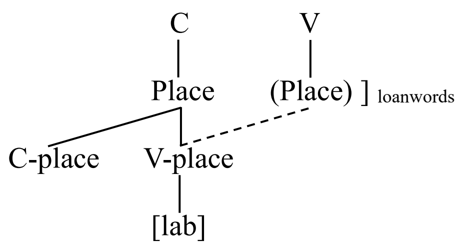
---

[2] Although epenthetic /u/ is no longer used as an epenthetic vowel in Korean, Oh (1992) discusses it in the earlier stages of English loanword adaptation.
[3] Oh (1992) uses the term 'palatal' in place of 'post-alveolar'.

(2.5) Coronal assimilation



(2.6) Labial assimilation



In (2.5), the V-place of the palatal consonant is specified with [cor] feature, and this feature is linked to the default epenthetic /ɨ/. As a result, the default epenthetic /ɨ/ may be realized as /i/ after the palatal consonant in English loanwords. Also, in (2.6) the V-place of the labial consonant is specified with [lab] feature which is linked to the default epenthetic /ɨ/. Consequently, the default epenthetic /ɨ/ can be realized as /u/ after the labial consonant in loanwords. On the other hand, alveolar and velar consonants are not specified for their V-place, and no feature spreads to the default epenthetic /ɨ/. As a result, the default epenthetic /ɨ/ is realized as it is, with no specified place feature.

In addition, epenthetic /ɨ/ and /i/ occur in different linguistic environments.

Table 2.1 Linguistic environments for epenthetic /ɨ/ and /i/

	Epenthetic /i/	Epenthetic /ɨ/
Preceding consonant	After an English post-alveolar consonant (/ʒ/, /ʃ/, /ʤ/, /ʧ/)	After a consonant except English post-alveolar, nasal, and liquid consonants
Syllable type	In open syllables	In both open and closed syllables
Syllable position	Ultimate syllable	Any syllable
Examples	*fish* [p^{h}isi], *switch* [sɨwiʧ^{h}i], *bridge* [pɨliʧi]	*spring* [sɨp^{h}ɨliŋ], *crumble* [k^{h}ɨlʌmpɨl], *peak* [p^{h}ik^{h}ɨ]

As Table 2.1 shows, epenthetic /ɨ/ and /i/ appear in different linguistic contexts. Epenthetic /i/ is typically used after English post-alveolar consonants and appears in ultimate open syllables. In contrast, epenthetic /ɨ/ occurs after any consonant except English post-alveolar, nasal, and liquid consonants. Also, epenthetic /ɨ/ is found in both open and closed syllables and can appear anywhere within a word. Thus, epenthetic /ɨ/ is used in a wider range of environments in English loanwords in Korean than epenthetic /i/.

2.2 Production of vowel epenthesis

This section reviews prior studies on the phonetic properties of epenthetic vowels in various languages. While some languages have epenthetic vowels that differ acoustically from lexical vowels (Davidson 2006; Gouskova & Hall 2009; Hall & Sue 2018; Miner 1989), others such as Korean exhibit epenthetic vowels that are acoustically identical to lexical vowels (Kim 2009; Kim & Kochetov 2011; Shin & Iverson 2014). This section discusses cases where epenthetic vowels are phonetically distinct from lexical vowels, explores the reasons for these acoustic differences, and examines cases in Korean.

This section also reviews earlier studies on factors influencing the production of epenthetic vowels, including speech rate (Lindblom 1963; Miller 1981; van Son & Pols 1992) and speakers' proficiency in the source language (Kadenge & Mudzingwa 2012; LaCharité & Paradis 2005; Zellou 2011). Although these two factors are known to affect the production of epenthetic vowels, they have not yet been examined sufficiently in Korean. Thus, reviewing these studies helps in understanding how speech rate and language proficiency influence the production of epenthetic vowels and provides guidance for the analysis of Korean data.

2.2.1 Do epenthetic vowels differ phonetically from lexical vowels?

Across languages, epenthetic vowels and their corresponding lexical vowels exhibit different phonetic characteristics (Bellik 2019; Davidson 2006; Gouskova & Hall 2009, Hall 2013; Miner 1979). First, an epenthetic vowel is shorter than its corresponding lexical vowel (Davidson 2006; Gouskova & Hall 2009; Hall & Sue 2018; Miner 1989). For instance, the Ho-Chunk language, also called Winnebago, presents an interesting case due to differing explanations for the shorter duration of its epenthetic vowels. Some studies attribute this difference to gestural timing, while others explain it in terms of syllable weight and phonological units observed in morphological patterns. Therefore, this language serves as a case study of how a single phonological phenomenon can be interpreted from multiple theoretical perspectives, showing the complexity in the phonetic realization of epenthetic vowels.

In Winnebago, consonant clusters that contain a voiceless obstruent followed by a sonorant are not permitted. To resolve this, the vowel immediately following the sonorant is duplicated and inserted between the voiceless obstruent and the following sonorant (e.g., /hipres/ [hiperés] 'know', /hikroho/ [hikòrohó] 'prepare 2sg'). This process is known as Dorsey's Law. This rule generates CVRV sequences, where the first syllable contains an epenthetic vowel. According to previous studies (Hall & Sue 2018; Miner 1979; Susman 1943), the epenthetic vowel in the first syllable is shorter in duration than the lexical vowel in the second syllable. For example, Hall and Sue (2018) analyzed Miner's archived recordings (Miner 1979, 1989) and compared CVRV sequences created by Dorsey's Law with lexical CVRV sequences. The findings show that CVRV sequences formed through Dorsey's Law are noticeably shorter in duration than lexical CVRV sequences. Thus, Hall and Sue (2018) argue that epenthetic vowels in Winnebago are shorter than their lexical counterparts.

There are several reasons proposed to explain why epenthetic vowels in Winnebago are shorter in duration. For example, according to Steriade (1990), Dorsey's Law does not involve introducing a completely new vowel articulation. Instead, in CVRV sequences, the two vowels are part of a single continuous articulatory movement. The timing of the sonorant is adjusted and overlaps the vowel gesture, creating the effect of two separate vowels (Browman & Goldstein 1986). This timing shift causes what would typically be pronounced as one syllable to sound like two syllables. Steriade (1990:390) represents the following gestural timing for the change from /pra/ to [para].

(2.7) Tier Gestures

```
(2.7)   Tier                          Gestures
                                         a
        Tongue body   [ – – – – – – – – – – – – – – – – – – – – – – – – – – – ]
                               r
        Tongue tip      [ – – – – – ]
                           p
        Lips          [ – – – – – ]
```

```
(2.8)   Tier                          Gestures
                                         a
        Tongue body   [ – – – – – – – – – – – – – – – – – – – – – – – – – – – ]
                                        r
        Tongue tip                  [ – – – – – ]
                           p
        Lips          [ – – – – – ]
```

In (2.7), two consonantal gestures overlap in time during pronunciation for [pra]. Also, the articulation of the tongue tip and the tongue body begins almost simultaneously. However, if the onset of a sonorant [r] is delayed, the overlap between the consonantal gestures disappears, as shown in (2.8). As a result, a vowel gesture appears between the two consonants /p/ and /r/. In other words, a fully separate vowel emerges between the two consonants /p/ and /r/, where they were previously pronounced consecutively. This causes the originally monosyllabic word to become disyllabic in Winnebago.

In contrast, Alderete (1995) argues that CVRV sequences are quantitatively less than a sequence of two light syllables such as CVCV sequences since CVRV sequences are parsed as single heavy syllables. This structural difference on syllable count may cause the shorter duration of CVRV sequences. To support this argument, Alderete (1995) uses the regular pattern of reduplication in Winnebago. Winnebago verb stems typically follow three shapes: CVV(C), CVCV(C), and CVVCV(C) (Alderete 1995; Susman 1943).

(2.9) CVCV(C)
waší ‘to dance’ → wašíší ‘to dance a bit, stop, and dance again’

CVVCV(C)
mąąnį́ ‘to walk’ → mąąnį́nį́ ‘to walk a little’

CVV(C)
xˈée ‘to drip’ → xˈeexˈé ‘drop earrings’

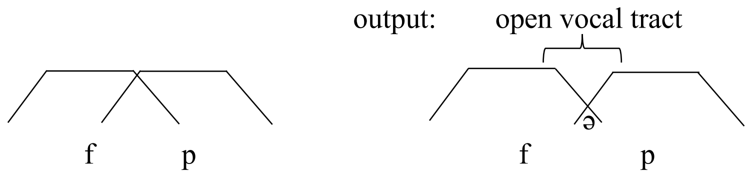
In (2.9), these forms are reduplicated by associating the stem-final material to a suffixal template composed of a single syllable. When the stem contains a heavy syllable such as the CVVC form, the single-syllable reduplicant appears to be inserted between the CVV portion and the final consonant of the stem as an infix (e.g., *juuk* → [juujuk] 'tender', *zook* → [zoozok] 'slippery'). These patterns provide evidence for the analysis that the reduplicant follows a single-syllable template. Alderete (1995:36) provides the following reduplicated CVRV sequences.

(2.10)	xará	→	xàraxára	'in slices or leaves'
	sará	→	sàrasára	'bald in spots'

In (2.10), the entire CVRV sequence is reduplicated, indicating that the reduplication process preserves the CVRV sequence as a single unit rather than breaking it into smaller parts such as CV and RV. That is, even though the CVRV sequence might resemble two light syllables such as CVCV, it functions as one syllable within Winnebago phonological structures. Interpreting CVRV sequences as single heavy syllables explains why they are shorter than two light syllables. Additionally, viewing CVRV sequences as single units makes their reduplicated forms align with patterns observed elsewhere in the language, such as in (2.9).

English also has a shorter epenthetic vowel compared to its lexical vowel. Davidson (2006) found that native English speakers tend to use an epenthetic schwa to repair phonotactically illicit consonant clusters, and this schwa shows the shorter duration than a lexical schwa in English. Davidson (2006) and Smorodinsky (2002) argue that 'mistiming' caused by the failure to pronounce consonant sequences in non-native languages with the correct overlapping gestural coordination results in the insertion of an epenthetic default vowel, which acts as a transitional vowel in this case. Davidson (2006:117) suggests the following gestural overlap for transitional schwa formation.

(2.11) target:



(2.11) demonstrates how a transitional schwa emerges between two consonants when their articulatory gestures fail to completely overlap. In (2.11), each consonant is depicted as a plateau, with the start of the plateau representing the moment the articulatory target is achieved and the end marking the release of the gesture. If the release of the first consonant does not overlap with the start of the second consonant's articulation, a gap appears between the two gestures. This gap produces a transitional schwa indicating a brief period of an open vocal tract between the consonants. Since this schwa results from gestural mistiming, its duration is likely shorter than that of a lexical schwa.

In addition to differences in vowel duration, epenthetic vowels can have different F1 and F2 formant values compared to lexical vowels. For instance, in Lebanese Arabic, epenthetic /i/ has different phonetic features from its corresponding lexical vowel (Gouskova & Hall 2009; Hall 2013). In this language, a typical case of vowel epenthesis occurs to break up consonant clusters consisting of three or four consonants, as well as clusters of two consonants in word-final position. In (2.12), vowel epenthesis is applied to break up a three-consonant cluster, and in (2.13), it is applied to break up a two-consonant cluster in word-final position.

(2.12)	/katabtla/	[katábitla]	'I wrote to him'
	/ʔibnna/	[ʔíbinna]	'our son'
(2.13)	/ʔism/	[ʔisim]	'name'
	/ʃiɣl/	[ʃiɣil]	'work'

Gouskova and Hall (2009) found that epenthetic /i/ in Lebanese Arabic has a lower F2 and shorter duration than lexical /i/, even though both are transcribed as /i/ at the surface representation. They explain these phonetic differences through the concept of incomplete neutralization. Phonological processes, once believed to eliminate contrasts entirely, often preserve subtle phonetic traces of underlying distinctions (Fougeron & Steriade 1997; Gouskova & Hall 2009; Warner et al. 2004). This phenomenon is known as incomplete neutralization. In Lebanese Arabic, the lower F2 and shorter duration of epenthetic /i/ reflect this incomplete neutralization, which may result from optional phonetic access to an intermediate stage during phonological derivation. While all Lebanese Arabic speakers share a fully neutralized surface form with epenthetic /i/, the speakers can access intermediate forms during phonetic implementation. Since the lower F2 brings epenthetic /i/ closer to /ɨ/ or /ə/, Gouskova and Hall (2009) suggest that these intermediate stages may correspond to /ɨ/ or /ə/. Thus, although the epenthetic vowel is phonologically represented as /i/, its actual realization can vary along a continuum between these central vowel qualities. To explain this, Gouskova and Hall (2009) apply Optimality Theory with Candidate Chains (OT-CC) (Becker 2006; McCarthy 2007). In standard Optimality Theory, surface forms are selected by evaluating candidate sets based on constraint rankings. However, OT-CC introduces the concept of derivations proceeding in steps. Each step represents a candidate in the chain, allowing the final surface form to reflect either the endpoint or an intermediate stage. This framework accounts for the phonetic realization of vowels that do not fully neutralize to [i] but instead manifest as intermediate forms like [ɨ] or [ə].

In Korean, previous studies (Kim 2009; Kim & Kochetov 2011; Shin & Iverson 2014) on the phonetic differences between epenthetic and lexical vowels show that both share similar F1, F2, and duration values. For example, Kim and Kochetov (2011) found that the duration, F1, and F2 formant values of epenthetic vowels in word-final positions of English loanwords closely match those of lexical vowels. Additionally, coarticulatory effects from adjacent consonants influence the formants of both epenthetic and lexical vowels. For example, F2 values are lowered when the preceding consonant is labial, and raised when it is coronal, due to the coarticulatory effects of consonant place on nearby vowels. Kim (2009) also investigated the phonetic differences between epenthetic /ɨ/ and lexical /ɨ/ in word-internal positions of English loanwords in the Kyungsang dialect of Korean and found no significant differences between them. Kim (2009) examined whether epenthetic /ɨ/ differs phonetically from lexical /ɨ/ by analyzing their duration, F1, and F2 values. The experiment involved participants reading English loanwords, English nonce words, and Korean lexical words within a carrier sentence. The results revealed no significant phonetic difference between epenthetic and lexical vowels. Epenthetic vowels were not shorter or more centralized. In fact, epenthetic vowels were slightly longer than lexical vowels, contradicting the expectation that they would be less prominent. Additionally, English nonce words showed slightly longer and more centralized vowels than English loanwords, likely due to the unfamiliarity of the forms. However, all these differences were not statistically significant.

2.2.2 What factors affect the production of epenthetic vowels?

The production of epenthetic and lexical vowels can be influenced by different speech rates (Bellik 2019; Lindblom 1963; Miller 1981; van Son & Pols 1992) and speakers' proficiency in the source language (Kadenge & Mudzingwa 2012; LaCharité & Paradis 2005; Zellou 2011). Despite the influence of these two factors on vowel production, their role in Korean still remains largely unexplored. Therefore, this section reviews previous studies on these factors and discusses how their findings apply to the case of Korean.

2.2.2.1 Different speech rates

Previous studies indicate that speech rate can lead to differences in the phonetic realization of the same vowel. In the case of vowel duration, it clearly decreases at a fast speech rate compared to a normal speech rate (Lindblom 1963; Miller 1981; van Son & Pols 1992). In addition to short vowel durations, vowels are prone to centralization when speech rate increases (Agwuele et al. 2008; Harmergnies & Poch-Olive 1992; Hernandez et al. 2023; Hirata & Tsukada 2009; Nadeu 2014). For example, Hernandez et al. (2023) investigate the effect of stress and speech rate on vowels in Central Mexican Spanish. The results show that although the degree of centralization varies for each vowel, the vowels exhibited centralization as speech rate increased. Additionally, vowel centralization becomes more pronounced for unstressed vowels at faster speech rates, and unstressed /a/ and /u/ tend to be more centralized at faster speech rates compared to their corresponding stressed ones. Also, Agwuele et al. (2009) focused on how different speech rates influence the articulatory and acoustic relationship between consonants and vowels in American English by investigating formant transitions and coarticulation patterns. According to Agwuele et al. (2009), the fast speech rate leads to increased coarticulation, resulting in hypoarticulated spectral reduction which is related to vowel centralization.

If a vowel is underspecified, it tends to be more centralized than vowels that are fully specified. For example, the backness and/or rounding of vowels in some languages such as Marshallese (Bender 1968; Choi 1992; Vaux & Samuels 2015) and Kabardian (Colarusso 1992) are underspecified in the underlying representation. Bender (1968) and Choi (1992) argue that while vowel height is specified in the underlying representation in Marshallese, vowel backness and rounding are underspecified and determined by adjacent consonants. That is, the F2 formant values of vowels are influenced by the consonantal contexts. Flemming (2004:250) explains that "backness and rounding are governed by minimisation of effort. This means that they are realised as smooth transitions between preceding and following consonants, which frequently results in central or centralised vowel qualities." As a result, underspecification may lead to the centralized articulation of vowels in the language. Epenthetic /ɨ/ in Korean also shows similar characteristics to Marshallese vowels. According to Oh (1992), epenthetic /ɨ/ is specified as [+high], but its backness is underspecified in English loanword adaptations. That is, epenthetic /ɨ/ can have a higher F2 than lexical /ɨ/ due to centralization. However, previous studies (Kim 2009; Kim & Kochetov 2011; Shin & Iverson 2014) comparing the phonetic properties of epenthetic vowels and their corresponding lexical vowels found no F2 differences between them at a normal speech rate during read speech. In read speech, speakers tend to articulate more deliberately, leading to minimal phonetic reduction. This careful articulation may reduce the phonetic distinctions between epenthetic /ɨ/

and lexical /ɨ/. On the other hand, in fast speech, phonetic reduction such as segment deletion, vowel shortening, or incomplete articulation can clearly occur (Greenberg 1999; Tucker & Mukai 2023; Warner & Tucker 2011). Therefore, this study investigates the phonetic differences between epenthetic /ɨ/ and lexical /ɨ/ in Korean fast speech, as significant phonetic reduction in fast speech may affect the realization of epenthetic /ɨ/.

2.2.2.2 Speakers' abilities in the source language

Speakers' proficiency in the source language can influence how a loanword is adapted, resulting in different phonological forms of the same word (Kadenge & Mudzingwa 2012; LaCharité & Paradis 2005; Zellou 2011). For example, Kadenge and Mudzingwa (2012) suggest that monolingual chiShona speakers and bilingual chiShona-English speakers apply different phonological rules when adapting English loanwords into chiShona, a southern Bantu language spoken in Zimbabwe. One significant distinction between English and chiShona lies in their syllable structures. ChiShona prohibits consonant clusters in onset positions. As a result, vowel epenthesis is used to simplify these clusters in English loanwords in chiShona.

(2.14)	protein	[pùróténì]
	stroke	[sìtìrókù]
	flute	[fùrétí]

In (2.14), vowel epenthesis is applied to break up consonant clusters /pr/, /str/, and /fl/ in onset positions. While monolingual chiShona speakers consistently use vowel epenthesis in this position, many bilingual speakers of chiShona and English often omit this process, allowing consonant clusters to remain in onset positions.

(2.15)	English *protein*:	monolingual form [pùróténì]	bilingual form [próténì]
	English *stroke*:	monolingual form [sìtìrókù]	bilingual form [stìrókù]
	English *flute*:	monolingual form [fùrétí]	bilingual form [flùtí]

As in (2.15), bilingual speakers produce consonant clusters in the onset positions while monolingual speakers use vowel epenthesis.

To explain the different adaptation processes of monolinguals and bilinguals in chiShona, Kadenge and Mudzingwa (2012:145) suggest the set of constraints based on Archangeli and Langendeon (1997) and Kager (1999) with different constraint rankings.

(2.16) *[$_\sigma$CC: Onsets are simple.

*C]$_\sigma$: Syllables are open.

*COMPLEXPEAK: Long vowels and diphthongs are prohibited.

MAX-IO: Input segments must have output correspondents.

DEP-IO: Output segments must have input correspondents.

IDENT-V: The features of a vowel in the input are identical to those of a corresponding vowel in the output.

(2.17) *[$_\sigma$CC >> *C]$_\sigma$ >> *COMPLEXPEAK >> MAX-IO >> DEP-IO >> IDENT-V

*C]$_\sigma$ >> *COMPLEXPEAK >> MAX-IO >> DEP-IO >> IDENT-V >> *[$_\sigma$CC

In (2.17), the first ranking is used for monolingual speech, and the second for bilingual speech, as shown in Tableau 2.1 (Kadenge & Mudzingwa 2012:147) and Tableau 2.2 (Kadenge & Mudzingwa 2012:148).

Tableau 2.1 Complex onsets in monolingual speech

/prəʊti:n/	*[$_\sigma$CC	*C]$_\sigma$	*COMPLEXPEAK	MAX-IO	DEP-IO	IDENT-V
[pró.tén]	*!	*				**
[pù.ró.tén]		*!			*	**
[pù.ró.té:.nì]			*!		**	**
[pù.ró.té]				*!	*	**
→[pù.ró.té.nì]					**	**

In Tableau 2.1, the optimal candidate is the one that minimally violates the lowest-ranked constraints, DEP-IO and IDENT-V. This tableau demonstrates that monolingual chiShona speakers strictly adhere to native phonological constraints when adapting English loanwords.

Tableau 2.2 Complex onsets in bilingual speech

/prəʊti:n/	*C]$_\sigma$	*COMPLEXPEAK	MAX-IO	DEP-IO	IDENT-V	*[$_\sigma$CC
[pró.tén]	*!				**	*
[pù.ró.tén]	*!			*	**	
[pù.ró.té:.nì]		*!		**	**	
[pù.ró.té]			*!	*	**	
[pù.ró.té.nì]				*!*	**	
→[pró.té.nì]				*	**	*

Tableau 2.2 tableau reflects the phonological adaptations produced by chiShona-English bilinguals who are influenced by both chiShona and English phonologies. In bilingual speech, *[$_\sigma$CC is ranked lower, allowing for the complex onsets in English loanwords in chiShona. Thus, the optimal candidate may retain certain English consonant clusters in chiShona-English bilingual speech.

In addition, chiShona-English bilinguals use some sounds that are absent in chiShona when adapting loanwords from English. For instance, according to Kadenge and Mudzingwa (2012), chiShona lacks the consonant /l/, which chiShona monolinguals typically replace with /r/ during English loanword adaptation. However, chiShona-English bilinguals preserve the /l/ sound, as seen in the adaptation of the English word *flute* [flùtí] in (2.14). This demonstrates that many chiShona-English bilinguals rely on English phonology when incorporating English loanwords into chiShona.

Zellou (2011) also found that Moroccan Arabic-French bilinguals produce /u/ differently in French loanwords in Moroccan Arabic and native Moroccan Arabic words. Specifically, the F1 formant values of /u/ in French loanwords were significantly higher than those in native Moroccan Arabic words. This indicates that /u/ in French loanwords is articulated with a lower tongue position compared to /u/ in native Moroccan Arabic words, making /u/ similar to /ɔ/. As shown in (2.18) (Zellou 2011:103), /ɔ/ in native French words is adapted as /u/ in French loanwords in Moroccan Arabic. Therefore, Moroccan Arabic-French bilinguals may use /ɔ/, not /u/ when pronouncing French loanwords during Moroccan Arabic speech.

(2.18)		French	Moroccan Arabic
	car	[otɔmɔbil]	[t̥umubil(a)]
	bus	[otɔbys]	[t̥ubis]

Zellou (2011) explains this result based on LaCharité and Paradis's theory (2005). LaCharité and Paradis (2005) argue that bilinguals face two competing requirements when producing loanwords. These demands include maintaining a precise mental representation of the word as it exists in the source language while also adapting it to fit the phonological rules of the recipient language. As a result, bilinguals' pronunciation of loanwords may reflect both requirements, and the phonetic characteristics of loanwords produced by bilinguals may differ from those of native words in the recipient language. In Zellou (2011)'s study, the vowel /a/ pronunciation of French loanwords and native Moroccan Arabic words showed similar phonetic features. Since both Moroccan Arabic and French have /a/, there is no reason for bilingual speakers to have a different mental representation of /a/ in French and Moroccan Arabic. On the other hand, in the case of /u/, strong evidence of the two competing requirements became apparent during the adaptation of French loanwords. /u/ in French loanwords was pronounced lower than /u/ in native Moroccan Arabic words. This result may be due to the fact that the corresponding vowel in the original French word is /ɔ/, which has a lower articulation compared to /u/. In other words, the lower articulation of /u/ in loanwords reflects the influence of the source language on the adaptation process. This pattern shows how bilingual speakers navigate between the phonetic features of French and the phonological structure of Moroccan Arabic. The phonetic properties of the French vowel are preserved to some extent in loanwords, but they are simultaneously modified to conform to the phonological rules of Moroccan Arabic.

Based on previous research (Kadenge & Mudzingwa 2012; LaCharité & Paradis 2005; Zellou 2011), there is a possibility that Korean-English bilinguals use English [ɨ] instead of Korean /ɨ/ in English loanwords in Korean. In my earlier study (2022) based on passage-level read speech, the findings showed that although the F1 formant values and durations of epenthetic /ɨ/ and lexical /ɨ/ are comparable, epenthetic /ɨ/ has a higher F2 than lexical /ɨ/ in the speech of Korean-English bilinguals. Thus, when pronouncing English loanwords in Korean, Korean-English bilinguals may opt for English [ɨ] over Korean central /ɨ/ with slight tongue retraction. To determine whether the higher F2 of epenthetic /ɨ/ is shaped by bilingualism, this study examines the production of epenthetic /ɨ/ in English loanwords during passage-level read speech by monolingual Korean speakers.

2.3 Perception of vowel epenthesis

This section examines how perception influences the loanword adaptation process based on previous studies (Broselow 2003; Kenstowicz 2003; Peperkamp & Dupoux 2003; Yip 2006), as the perceptual view accounts for phenomena that the traditional phonological grammar-based explanation fails to explain in English loanword adaptations in Korean. Moreover, this section reviews the factors that shape native Korean listeners' perception of epenthetic vowels.

2.3.1 How does perception affect loanword adaptation?

The traditional linguistic approach to loanword adaptation explains how words from a source language are integrated into a recipient language by focusing on the phonological grammar of the recipient language. This model assumes that the input to loanword adaptation is the phonetic representation of the source language word, while the output is shaped by the phonological rules and constraints of the recipient language. It means that the phonetic form of the source language is accurately perceived and stored as an underlying representation. However, during speech production, the word is adapted based on the phonological grammar of the recipient language. For example, an English word *spring* may be correctly perceived by native Korean listeners as [spɹɪŋ], but when pronounced as a loanword in Korean, epenthetic /ɨ/ occurs to break up the consonant cluster by Korean phonological rules. This reflects the role of the recipient language's phonology in shaping the final adapted form.

On the other hand, according to Peperkamp and Dupoux (2003), all modifications in loanwords occur during the perception process. The transformation from an underlying representation to a surface representation governed by the phonological grammar of the recipient language is not necessary. Instead, the role of phonology in loanword adaptation is limited to shaping how words from the source language are perceived by native speakers of the recipient language. Peperkamp and Dupoux (2003) argue that native listeners initially perceive foreign words as an acoustic signal. Then, a phonetic decoding module may begin to function. The foreign input sound is mapped to the closest available phonetic category, based on either acoustic proximity or articulatory gestures. During this process, if a sound or structure does not exist or is not allowed in the recipient language, it becomes difficult for native listeners to distinguish it from a similar sound or structure that does exist in the recipient language (Best 1994; Dupoux et al. 1999; Hallé et al. 1998). For example, native Korean listeners may have difficulty distinguishing between the correct English pronunciation [spɹɪŋ] and a form [sɨpʰɨliŋ]. Finally, the native listener's phonological decoding module may map the surface representation onto the potential underlying representation. Thus, the underlying representation may have an epenthetic vowel already such as /sɨpʰɨliŋ/ in Korean.

However, many studies argue that loanword adaptations may not be fully understood by considering only perception or phonology. That is, loanword adaptation involves both the recipient's phonological grammar and perceptual similarity between the source and recipient languages (Broselow 2003; Kenstowicz 2003; Yip 2006). These studies underscore the importance of perceptual mechanisms in loanword adaptation, demonstrating that the way foreign sounds are perceived through the native language's phonological system profoundly influences their integration. Grounded in the prevailing view that phonological grammar involves phonological constraints ranked in a language-specific manner, these studies integrate perception into the framework of Optimality Theory. For example, Kenstowicz (2003) accounts for the asymmetry between a lateral /l/ and rhotics with the dorsal feature in loanword adaptation in Fon language spoken in Benin and Togo. The lateral /l/ is consistently mapped to /l/ in loanword adaptation in Fon.

(2.19) lame [lǎmũ̀]

dollar [dǎlà]

flower [flówà]

col [kɔ́lù]

As in (2.19), the lateral /1/ is always mapped to /l/ in loanword adaptation in Fon regardless of whether /1/ appears in prevocalic, preconsonantal or word-final position. However, rhotics with the dorsal feature show more complex phonological changes in loanword adaptation in Fon. If these rhotics appear in a prevocalic position, they are mapped to /ʁl/. However, if these rhotics are used in preconsonantal or word-final positions, they are deleted in loanword adaptation in this language.

(2.20) rideau 'curtain' [ʁlīdô]

gare 'station' [gǎ]

torche 'torch' [tɔ́tʃì]

As (2.20) shows, rhotics are mapped to /ʁl/ in prevocalic positions, but they are deleted in preconsonantal or word-final positions. Kenstowicz (2003) argues that these rhotics in those positions are perceptually very weak, so they may be perceived as almost zero. This fact may cause the deletion of rhotics in these particular positions. To account for this perceptual explanation, Kenstowicz (2003) suggests that the grammar can influence loanword adaptation at two distinct stages, a perception grammar and a production grammar as shown in (2.21) (Kenstowicz 2003:99).

(2.21)

	Perception		Production	
[xxx] →	[UG + L1] →	/yyy/ →	[UG + L1] →	[zzz]
loan source		lexical rep.		output

According to Kenstowicz (2003), there are two separate grammars in loanword adaptation, and the perceptual similarity can be explained in the perception grammar. Since rhotics in preconsonantal or word-final positions are perceptually perceived as zero, they must be deleted in a perception grammar. To explain this process, Kenstowicz (2003) used the following constraints.

(2.22) Dep-V: No vowel epenthesis

Max-C: No consonant deletion

*r/___#,C: No /r/ which is not prevocalic

*C/___#,C: No consonant which is not prevocalic

Based on Itô and Mester (1995), two separate grammars apply different rankings of faithfulness constraints as shown in (2.23) (Kenstowicz 2003:100).

(2.23) Dep-V, *r/___#,C >> Max-C

Max-C, *C/___#,C >> Dep-V

The first ranking in (2.23) explains the deletion of rhotics in preconsonantal or word-final positions, such as *gare* [gǎ] and this ranking applies in the perception mapping. The second ranking in (2.23) accounts for words with epenthesis, such as *col* [kɔ́lù], in the production mapping. Tableau 2.3 (Kenstowicz 2003:100) represents deletion, and Tableau 2.4 (Kenstowicz 2003:101) represents epenthesis.

Tableau 2.3 The process of two grammars for deletion

a. Perception mapping

/gar/	Dep-V	*r/___#,C	Max-C
gar		*!	
gari	*!		
→ga			*

b. Production mapping

/ga/	Max-C	*C/___#,C	Dep-V
→ga			
gari			*!

Tableau 2.4 The process of two grammars for epenthesis

a. Perception mapping

/kɔl/	Dep-V	*r/___#,C	Max-C
→kɔl			
kɔlu	*!		
kɔ			*!

b. Production mapping

/kɔl/	Max-C	*C/___#,C	Dep-V
kɔl		*!	
→kɔlu			*
kɔ	*!		

As in Tableaux 2.3 and 2.4, separate perception and production grammars with differently ranked faithfulness constraints exist in loanword adaptations. The output of perception mapping is going to be the input of production mapping, and the output of production mapping is an actual surface form. Specifically, [ga] in Tableau 2.3a and [kɔl] in Tableau 2.4a selected as the optimal output in each perception mapping become the input for each production mapping: /ga/ in Tableau 2.3b and /kɔl/ in Tableau 2.4b. As a result, [ga] and [kɔlu] which violate the lowest-ranked constraint Dep-V are selected as the final optimal surface forms in each production mapping.

As discussed in this section, perception plays an important role in loanword adaptation across many languages. In Korean, since perception also influences loanword adaptation, vowel epenthesis and the factors affecting it have been examined from a perceptual perspective which is discussed in the next section.

2.3.2 What phonetic factors increase vowel epenthesis in Korean?

The perceptual approach can explain aspects that the traditional phonological grammar-based account cannot adequately address. For example, in Korean, the traditional explanation does not sufficiently account for unnecessary vowel epenthesis (e.g., /ɨ/ epenthesis after a permissible Korean coda) and the different repair strategies used to resolve consonant clusters in English loanwords and Korean lexical words (e.g., epenthesis in English loanwords, deletion in Korean lexical words). On the other hand, fundamentally and simply, the perceptual view explains vowel epenthesis as a result of the perceptual similarity between English inputs and Korean outputs. Even when vowel epenthesis is unnecessary, English inputs are perceptually more similar to Korean outputs with epenthesis than to Korean outputs without it. Likewise, English inputs sound more similar to Korean outputs with epenthesis than to Korean outputs with deletion.

Interestingly, surrounding phonetic environments can enhance the use of /ɨ/ epenthesis, whereas /i/ epenthesis consistently occurs in a specific phonological context in Korean. In the case of /i/ epenthesis, it always occurs after English words ending in one of English post-alveolar consonants /ʒ/, /ʃ/, /ʤ/, and /ʧ/. If an English word ends in /ʒ/ or /ʃ/, these consonants change to [ʧ] and [s], respectively, and /i/ epenthesis occurs after these sounds. If an English word ends in /ʤ/ or /ʧ/, these consonants are realized as [ʧ] and [ʧʰ], respectively, and /i/ epenthesis occurs after them.

(2.24) English loanwords ending in post-alveolar consonants

beige	[pɛiʧi]
fish	[pʰisi]
bridge	[pɨliʧi]
switch	[sɨwiʧʰi]

As shown in (2.24), /i/ epenthesis must occur after one of English post-alveolar consonants without exception.

In contrast, /ɨ/ epenthesis can either occur or not depending on the linguistic environments. Previous research (Kang 2003; Kim 2008; Nam & Southard 1994) on /ɨ/ epenthesis found phonological patterns in English CVC monosyllabic structures. First, /ɨ/ epenthesis does not occur after English nasal or liquid consonants.

(2.25) English loanwords ending in nasal or liquid consonants

steam	[sɨtʰim]
corn	[kʰon]
ring	[liŋ]

As (2.25) shows, /ɨ/ epenthesis does not occur after English nasals or liquids. This pattern also applies to English consonant clusters. For example, in *pulp*, *lamp*, and *hint*, /ɨ/ epenthesis occurs only at the end of the word, rather than occurring twice, as in desk [tɛsɨkʰɨ]. Next, /ɨ/ epenthesis must occur after English labiodental, dental, and alveolar fricatives /f/, /v/, /θ/, /ð/, /s/, and /z/.

(2.26) English loanwords ending in fricative consonants

graph	[kɨlæpʰɨ]
love	[lʌpɨ]
bathe	[pɛitɨ]
jazz	[ʧæʧɨ]
bus	[pʌsɨ]
dance	[tɛnsɨ]
golf	[kolpʰɨ]

In (2.26), /ɨ/ epenthesis always appears after those English fricatives, and this pattern extends to English consonant clusters as well. For instance, in *dance* and *gulf*, epenthetic /ɨ/ follows /s/ and /f/, respectively.

While the patterns of /ɨ/ epenthesis in English CVC monosyllabic structures in (2.25) and (2.26) have remained consistent, /ɨ/ epenthesis in those structures ending with a stop consonant has sparked much discussion. Previous studies (Kang 2003; Kim 2008; Nam & Southard 1994; Rhee & Choi 2001) investigated which linguistic factors influence /ɨ/ epenthesis in English CVC monosyllabic structures ending in a stop consonant based on a list of English loanwords such as the dictionary of Loanword in Korean (Pae 1970) and the National Academy of the Korean Language (National Institute of

Korean Language 1991) which includes approximately 5000 English loanwords and phrases taken from six newspapers and nine magazines published in 1990. For example, Kang (2003) and Kim (2008) investigated English CVC monosyllabic structures in the National Academy of the Korean Language (National Institute of Korean Language 1991). 447 English CVC monosyllabic structures ending in a stop consonant were identified. Among these 447 English words, half were introduced into Korean with /ɨ/ epenthesis. This variation is primarily observed after English voiceless stops, in contrast to the relatively consistent use of /ɨ/ epenthesis after English voiced stops. Specifically, while /ɨ/ epenthesis occurs 88% of the time after English voiced stops /b/, /d/, and /g/ (e.g., *kid* [$\mathrm{k^h}$itɨ]), it occurs only 39% of the time after English voiceless stops /p/, /t/, and /k/ (e.g., *mat* [mæ$\mathrm{t^h}$ɨ]). Next, the place of articulation of the final stops was examined. Of the 447 English words, 223 ended in a coronal stop with /ɨ/ epenthesis observed 72% of the time (e.g., *set* [sɛ$\mathrm{t^h}$ɨ]). For the 143 words ending in a dorsal stop, epenthesis occurred in 34% of cases (e.g., *gag* [kækɨ]). Among the 81 words with a final labial stop, /ɨ/ epenthesis was observed 21% of the time (e.g., *hoop* [hu$\mathrm{p^h}$ɨ]). In addition to the effect of adjacent consonants, /ɨ/ epenthesis is more likely to occur when the English pre-final vowel is tense rather than lax. Out of 447 English words that end with a stop consonant, 154 words had a tense vowel before the final consonant. In these cases, /ɨ/ epenthesis was observed 89% of the time (e.g., *beat* [pi$\mathrm{t^h}$]). Conversely, 283 words had a lax vowel, and /ɨ/ epenthesis occurred in 28% of these instances (e.g., *hit* [hi$\mathrm{t^h}$ɨ]). Kang (2003) includes all English lax and tense vowels, including diphthongs, so vowels with a clear tense-lax contrast are drawn from Kang (2003:231) and listed in Table 2.2.

Table 2.2 Frequency of /ɨ/ epenthesis by vowel tenseness

Pre-final vowel	Number of words	Epenthesis	No epenthesis	Optional epenthesis
/ɪ/	121	20 (16.5%)	93 (76.9%)	8 (6.6%)
/i/	21	19 (90.5%)	1 (4.8%)	1 (4.8%)
/ʊ/	9	3 (33.3%)	6 (66.7%)	0 (0.0%)
/u/	20	16 (80.0%)	1 (5.0%)	3 (15.0%)

As shown in Table 2.2, /ɨ/ epenthesis occurs more frequently when the pre-final vowel is tense rather than lax. Based on this finding, Kang (2003) argues that the release of the final consonant may also contribute to /ɨ/ epenthesis, as final stops in English are released more often after a tense vowel than after a lax vowel (Parker & Walsh 1981). Therefore, the tenseness of a pre-final vowel does not directly influence vowel epenthesis, but it may increase the likelihood of coda release, which is directly linked to /ɨ/ epenthesis.

Perceptual studies (de Jong & Park 2012; Jun 2002; Kim 2008; Kim 2021, 2022; Kwon 2017) have explored how linguistic factors influence native Korean listeners' perception of /ɨ/ epenthesis, and the perceptual results generally align with findings from lists of English loanwords. Native Korean listeners were more likely to perceive /ɨ/ epenthesis in English words ending in a released stop compared to an unreleased stop. Voiced stops also increased the perception of /ɨ/ epenthesis compared to voiceless stops. Furthermore, /ɨ/ epenthesis was perceived more frequently when the preceding vowel was tense rather than lax, and native Korean listeners perceived /ɨ/ epenthesis more often when the final stop was coronal or dorsal, compared to when it was labial. In addition to these factors, /ɨ/ epenthesis occurs more frequently in English monosyllabic words than in disyllabic words (Kim 2022), and when the final syllable is stressed rather than when it is not (Jun 2002).

While most factors show similar results across perceptual studies, the tenseness of the pre-final vowel remains a topic for further investigation, as Kim (2022) demonstrated that it has no effect on native Korean listeners' perception of /ɨ/ epenthesis. Therefore, this dissertation explores a potential reason for the different results regarding the tenseness of the pre-final vowel.

In the case of /i/ epenthesis, the noise duration of the final consonant is one of the contributing factors in this dissertation. de Jong and Park (2012) argue that sibilant codas elicit more perceived epenthetic vowels than non-sibilant codas, as native Korean listeners tend to misperceive the salient consonant noise as an additional vowel. Given that /i/ epenthesis occurs after English /ʒ/, /ʃ/, /ʤ/, or /ʧ/, it is possible that native Korean listeners may perceive epenthetic /i/ more frequently when the noise of the final consonant is longer than when it is short.

2.3.3 Do listeners' abilities in the source language affect vowel epenthesis?

The language experience of the source language can affect loanword adaptation patterns in the recipient language (Best & Tyler 2007; Boersma & Hamann 2009; Chang 2008; Kang 2009; Wang 2023). Specifically, experience and proficiency in the source language affect how well native speakers of the recipient language perceive the sounds from the source language. This view suggests that the degree to which speakers can perceive and differentiate sounds in the source language influences how they adapt those sounds into the recipient language. For example, according to the Perceptual Assimilation Model for L2 (PAM-L2) (Best & Tyler 2007), the similarity or difference between a native language (L1) and a second language (L2) sounds affects how easily L2 can be learned. It also predicts how functional monolinguals who rarely use or learn L2 perceive L2 sounds by relying heavily on their native language (Best & Tyler 2007). Best and Tyler (2007) argue that proficient L2 learners perceive sounds differently from functional monolinguals as they can discern not only subtle acoustic differences but also identify abstract and meaningful phonological patterns. Also, PAM-L2 explains three categorized patterns. First, Two-Category (TC) assimilation refers to the situation where two L2 sounds are clearly recognized as belonging to two different L1 phonemes. Second, Single-Category (SC) assimilation refers to the case where both L2 sounds are perceived as belonging to the same L1 phoneme, and neither sound fits better than the other. Last, Category Goodness (CG) difference describes a scenario in which both L2 sounds are perceived as fitting into the same L1 category, but one sound is a better match to the L1 sound, while the other is a slightly poorer fit. Varying degrees of perceptual effort and L2 learning experience can affect the process of these three different patterns (Best & Tyler 2007; Tyler et al. 2014; Wang 2023).

Previous studies (Chang 2008; Kang 2009; Smith 2006; Wang 2023) empirically explore whether different L2 proficiency levels lead to differences in the adaptation of the source language and how these proficiency differences affect the perception of source language sounds. For example, Smith

(2006) investigates deletion/epenthesis loanword doublets in Japanese. In this language, vowel epenthesis is the most commonly used strategy in loanword adaptations to transform illicit foreign consonant codas and clusters into permissible forms. However, deletion can also occur for the same purpose. Interestingly, loanwords adapted through deletion also have an epenthetic version, and this tendency has persisted from 19th to 20th-century loanwords in Japanese. For example, the English word *pocket* has both the deletion form [pok.ke] and the epenthetic form [po.ket.to] to repair the illicit English coda /t/. Also, due to the illicit consonant cluster in the English word *crank*, the word was adapted into Japanese as the deletion form [ka.ɾaɴ] and the epenthetic form [kɯ.ɾaɴ.kɯ]. Smith (2006) argues that the reason for the deletion process in loanword adaptations may be related to perception. Generally, loanwords are introduced into Japanese through written texts rather than spoken language (Lovins 1975; Miura 1993; Smith 2006). However, loanwords that undergo deletion may be influenced by perception rather than orthography. For example, Hawai'ian Japanese is spoken by a community that likely engaged in direct interaction with native English speakers, rather than relying mainly on English-language written materials, and English loanwords in this variety often exhibit cases of deletion (e.g., English *inside* [iɴ.sai]). The analysis of Japanese loanword doublets suggests that perceptual abilities play a key role in shaping adaptation, particularly in vowel epenthesis and deletion. In varieties like Hawai'ian Japanese, direct auditory exposure to English often leads to adaptations favoring deletion over epenthesis. These findings show that perceptual sensitivity to foreign languages significantly influences how loanwords are processed and adapted. This line of research underscores the importance of perception in the loanword adaptation process and argues that phonological loanword patterns are not solely determined by structural constraints in the recipient language but can also be shaped by speakers' perceptual mapping of the source language onto the recipient language. Building on this perspective, this dissertation investigates whether native Korean listeners' ability to discriminate between English tense and lax vowels affects their perception of /ɨ/ epenthesis. Specifically, the study examines whether native Korean listeners who can reliably distinguish this vowel contrast are more likely to perceive /ɨ/ epenthesis in English CVC monosyllabic structures with a pre-final tense vowel compared to those who cannot.

2.4 Hypothesis for production and perception of epenthetic vowels

First, this study aims to thoroughly explore the phonetic features of epenthetic and lexical vowels across normal and fast speech rates in Korean by comparing their phonetic characteristics both within each speech rate and between the two speech rates. This study expects the following results on epenthetic /ɨ/ and lexical /ɨ/:

(2.27) Epenthetic /ɨ/ and lexical /ɨ/ in sentence-level read speech at different speech rates

- Epenthetic /ɨ/ and lexical /ɨ/ have similar F1 and F2 formant values at the normal speech rate.
- Epenthetic /ɨ/ and lexical /ɨ/ have centralized F1 and F2 formant values at a faster speech rate compared to the normal speech rate.
- The F2 formant value of epenthetic /ɨ/ is more centralized than that of lexical /ɨ/ at the fast speech rate while they have similar F1 values.
- Epenthetic /ɨ/ and lexical /ɨ/ have similar durations at each speech rate.
- Epenthetic /ɨ/ and lexical /ɨ/ have shorter durations at the fast speech rate compared to the normal speech rate.

(2.28) Epenthetic /i/ and lexical /i/ in sentence-level read speech at different speech rates

- Epenthetic /i/ and lexical /i/ have similar F1 and F2 formant values and durations at each speech rate.
- Epenthetic /i/ and lexical /i/ have centralized F1 and F2 formant values at a faster speech rate compared to the normal speech rate.
- Epenthetic /i/ and lexical /i/ have shorter durations at the fast speech rate compared

to the normal speech rate.

(2.29) Passage-level read speech at the normal speech rate

- Epenthetic /ɨ/ and lexical /ɨ/ produced by monolingual Korean speakers have similar F1 and F2 formant values in passage-level read speech at the normal speech rate.

Next, this study seeks to comprehensively investigate the perceptual characteristics of vowel epenthesis across various linguistic environments. The study anticipates that vowel epenthesis is perceived more frequently under the following conditions:

(2.30) Perceived vowel epenthesis

- The release of the final consonant: Native Korean listeners perceive epenthetic /ɨ/ more frequently in English CVC monosyllabic structures when the final consonant is released than when it is unreleased.
- The noise duration of the final consonant: Native Korean listeners perceive epenthetic /i/ more frequently in English CVC monosyllabic structures when the final consonant has a long noise duration than when it has a short one.
- The voicing of the final consonant: Native Korean listeners perceive epenthetic /ɨ/ and /i/ more frequently in English CVC monosyllabic structures when the final consonant is voiced than when it is voiceless.
- The place of articulation of the final consonant: Native Korean listeners perceive epenthetic /ɨ/ more frequently in English CVC monosyllabic structures when the final consonant is either coronal or dorsal than when it is labial.
- Native Korean listeners with a better ability to distinguish between English tense and lax vowels tend to perceive higher rates of /ɨ/ and /i/ epenthesis in English CVC monosyllabic syllable structures with a pre-final tense vowel.

CHAPTER 3

PRODUCTION OF VOWEL EPENTHESIS

3.1 Introduction

This chapter explores the phonetic properties of epenthetic and lexical vowels in Korean, focusing on differences observed in passage-level read speech and across varying speech rates. By analyzing formant values and vowel durations, the study clarifies whether epenthetic vowels show distinct articulatory characteristics or align with their corresponding lexical vowels.

In my previous study (2022), while epenthetic /ɨ/ and lexical /ɨ/ in Korean share the same duration and F1 value, epenthetic /ɨ/ has a higher F2 than lexical /ɨ/. This result can be attributed to the bilingualism of the speakers. If speakers are bilingual in the source and recipient languages, they often transfer the pronunciation or phonetic characteristics of the source language into loanwords in the recipient language (Kadenge & Mudzingwa 2012; LaCharité & Paradis 2005; Zellou 2011). Since the F2 formant value of English [ɨ] is typically higher than that of Korean lexical /ɨ/, it is possible that the speakers in my previous study (2022) used the English [ɨ] in English loanwords in Korean. To investigate whether this F2 difference results from bilingual influence, this chapter analyzes speech produced by Korean monolinguals.

Next, this chapter investigates the phonetic differences between epenthetic and lexical vowels in Korean at normal and fast speech rates. The main objectives are to explore (a) the phonetic differences between epenthetic and lexical vowels at each speech rate, (b) formant centralization and vowel duration reduction of epenthetic and lexical vowels at the fast speech rate, and (c) the greater F2 centralization of epenthetic /ɨ/ compared to lexical /ɨ/ during fast speech.

Previous research (Browman & Goldstein 1990; Davidson 2006; Davidson & Stone 2003) suggests that epenthetic vowels might lack specific articulatory or acoustic targets, and their properties may be influenced by the articulation of neighboring consonants. As a result, these targetless epenthetic vowels are expected to differ inherently from lexical vowels. In Korean, however, Kim and Kochetov (2011) demonstrated that epenthetic vowels are fully articulated at a normal speech rate rather than functioning as transitional or targetless sounds. Since speech rate can influence the production of epenthetic and lexical vowels differently (Bellik 2019), examining their phonetic properties at different speech rates may help clarify whether Korean epenthetic vowels are fully realized or targetless.

3.2 Overview of methodology

In this study, vowel production experiments were designed to explore the differences in phonetic features (F1, F2, and vowel duration) between epenthetic and lexical vowels. The first set of production experiments investigates these phonetic differences in passage-level read speech, and the second set examines these features at normal and fast speech rates. The experiment on passage-level read speech was conducted first, followed by experiments at different speech rates to prevent the influence of fast speech on the results of the passage-level experiment at a normal speech rate. In the passage-level read speech experiment, native Korean speakers read two passages at their normal speech rate. In the different speech rate experiments, they first read the sentences twice at a normal speech rate, then read the same sentences as fast as possible within a limited time.

A total of 30 native Korean speakers participated in the production experiments. Twenty-five participants were recorded in various quiet locations such as a library study room and a seminar room in Seoul, Korea, while five participants were recorded in a sound-attenuated booth in the Linguistics Lab at the University of Georgia, USA. A Marantz digital recorder and a Shure headworn dynamic microphone were used for all recordings in the production experiments.

3.2.1 Participants

All 30 participants were born and raised in Seoul, Korea, which eliminates any potential dialectal variations that could affect the results of the production experiments. Among these participants, twenty-five currently live in Seoul and have never lived in an English-speaking country. The other five participants have lived in Georgia, USA, for less than a year. Even though they spend time in the USA, they continue to use Seoul Korean in their daily lives at school, work, or in social contexts based on the English Proficiency Self-Rating Questionnaire in Appendix A. Table 3.1 presents the participants' information.

Table 3.1 Dataset of participant information

Participant Number	Age	Months in English-speaking Country	English Proficiency	Recording Location
F1	34	0	A	Seoul, Korea
F2	29	0	C	Seoul, Korea
F3	30	0	B	Seoul, Korea
F4	32	0	A	Seoul, Korea
F5	28	0	A	Seoul, Korea
F6	33	0	A	Seoul, Korea
F7	30	0	B	Seoul, Korea
F8	30	0	C	Seoul, Korea
F9	32	0	C	Seoul, Korea
F10	27	0	C	Seoul, Korea
F11	31	0	A	Seoul, Korea
F12	35	0	A	Seoul, Korea
F13	35	0	A	Seoul, Korea
F14	30	3	D	UGA
F15	33	2	C	UGA
M16	32	0	D	Seoul, Korea
M17	29	0	D	Seoul, Korea
M18	35	0	C	Seoul, Korea
M19	33	0	D	Seoul, Korea
M20	29	0	B	Seoul, Korea
M21	32	0	C	Seoul, Korea
M22	28	0	D	Seoul, Korea
M23	35	0	B	Seoul, Korea
M24	33	0	D	Seoul, Korea
M25	35	0	B	Seoul, Korea
M26	28	0	A	Seoul, Korea
M27	35	0	D	Seoul, Korea
M28	30	5	B	UGA
M29	34	2	B	UGA
M30	31	5	B	UGA

Table 3.1 includes participants' numbers, ages, genders (F = female; M = male), duration of stay in the USA (in months), English proficiency levels, and recording locations. The participants' average age is 32.75 years, and their average duration of residence in the USA is 3.4 months. Their English proficiency levels were determined using the English Proficiency Self-Rating Questionnaire, detailed in Appendix A. This questionnaire is adapted from Park and Ziegler's (2014) questionnaire, which is based on the Common European Framework of Reference for Languages (CEFR). It is publicly accessible on the IRIS

database[4] and can be used for research purposes. Participants rated their frequency of English use in their daily lives and their current English proficiency in reading, listening, speaking, and writing on five-point scales (ranging from 1 to 5). The total English proficiency scores from these four skills were combined to estimate their overall English proficiency. These scores were then divided into four groups according to CEFR: (a) Group A (17 to 20) with eight participants in this study, (b) Group B (13 to 17) with eight participants, (c) Group C (9 to 12) with seven participants, and (d) Group D (4 to 8) with seven participants.

The purpose of the English Proficiency Self-Rating Questionnaire in this experiment is to assess participants' different levels of English proficiency and ensure that the number of participants is evenly distributed across all proficiency levels.

3.2.2 General procedures

Following the completion of the English Proficiency Self-Rating Questionnaire via Google Forms, the production experiments were conducted with the participants. Before starting the production experiment, participants received detailed instructions, including reading two passages displayed on a computer screen in Word at their normal speech rate in Korean. Once participants finished reading the first passage, they had the option to take a short break before moving on to the second passage. After completing the second passage, they took a 5-minute rest before starting to read sentences at different speech rates.

The production experiment at the normal speech rate was conducted first, followed by the experiment at the fast speech rate. In the experiment at the normal speech rate, participants received instructions which included reading each sentence twice on a computer screen in PowerPoint at their normal speech rate in Korean and practiced with trials. After completing the three practice trials, they

[4] https://iris-database.org/

proceeded with the actual experiment on epenthetic /ɨ/, followed by the experiment on epenthetic /i/. After completing experiments on both epenthetic /ɨ/ and /i/, participants took an optional five-minute break. They then began the experiments on lexical /ɨ/ and /i/. Participants first took part in the experiment on lexical /ɨ/, followed by the experiment on lexical /i/. Upon finishing the experiments on lexical vowels, participants were given an optional five-minute break. Then, the experiments at the fast speech rate began. In the experiments at the fast speech rate, the procedures used in the production experiments at the normal speech rate were replicated at the fast speech rate, following the specific order: epenthetic /ɨ/, epenthetic /i/, lexical /ɨ/, and lexical /i/, with an optional five-minute break between each experiment. Participants received detailed directions including reading each sentence as quickly as possible within five seconds. They practiced the three trials with epenthetic /ɨ/ first. In each trial, when participants pressed the Enter key, the first beep sound played one second later, and participants read a sentence on a computer screen in PowerPoint as quickly as possible until the second beep played automatically five seconds later. The same procedure used in the trials was applied to the actual production experiments at the fast speech rate.

3.2.3 Stimuli

3.2.3.1 Vowel production in passage-level read speech

Target words containing epenthetic /ɨ/ and lexical /ɨ/ were presented in two passages which are listed in Appendix B. The English loanword stimuli are all actual words consisting of at least two syllables (e.g., *world* [wʌltɨ]) and at most five syllables (e.g., *privacy* [pʰɨlɑipʌsi]). Thus, epenthetic /ɨ/ can occur anywhere within words.[5] These English loanword stimuli were designed with the specific controls on surrounding place of articulation, syllable structure, and vowel position within the word.

[5] In Korean, vowels tend to become centralized in non-initial positions during spontaneous speech (Shin 2018; Yoon & Kim 2015). However, this study focuses on read speech at the normal speech rate, so the position within the word is not considered a factor affecting vowel formants in this study.

First, generally consonants with different places of articulation affect the F2 formant values of the following vowels in many languages (Cooper et al. 1952; Kerdpol 2012; Kim & Kochetov 2011; Liberman et al. 1954). Specifically, F2 values tend to decrease after labial consonants but increase after coronal consonants due to coarticulatory effects from the consonant's place of articulation on adjacent vowels (Kim & Kochetov 2011). Therefore, in this study, the preceding consonants of epenthetic /ɨ/ are categorized into three places of articulation in English loanword stimuli: Korean bilabial /p, p^h/, alveolar /t, t^h/, and velar /k, k^h/.

Next, regarding vowel durations, vowels in open syllables are typically pronounced longer than those in closed syllables in many languages (Choi & Jun 1998; Curtis 2002; Monsen 1974; Rositzke 1939). In the English loanword stimuli, epenthetic /ɨ/ occurs in both open and closed syllables (e.g., open syllable: *dog* [tokɨ]; closed syllable: *eagle* [ikɨl]). In closed syllables, epenthetic /ɨ/ occurs only in the specific contexts: (a) between a consonant and /l/ (e.g., *circle* [sʌk^hɨl]), and (b) in the 'sm' consonant cluster (e.g., *prism* [p^hɨlitʃɨm]). In the case of the 'sm' consonant cluster, it appears in a very limited number of English loanwords in Korean, so epenthetic /ɨ/ in closed syllables occurs between a consonant and /l/ in the English loanword stimuli. As a result, epenthetic /ɨ/ occurs between the English clusters /pl/, /tl/, /kl/, /bl/, /dl/, and /gl/ meaning that the English loanword stimuli include closed syllables [p^hɨl], [t^hɨl], [k^hɨl], [pɨl], [tɨl], and [kɨl]. Also, the position of a vowel within a word can influence its duration. In many languages, vowels in final word positions are generally longer (Umeda 1975; van Santen 1992). Hence, epenthetic /ɨ/ is categorized as occurring in either a non-final syllable (e.g., *gram* [kɨlæm]) or the final syllable (e.g., *mug* [mʌkɨ]) in the English loanword stimuli.

For lexical /ɨ/, the Korean stimuli consist of actual words, and the same factors used for epenthetic /ɨ/ were applied as controls: (a) preceding consonants with different places of articulation, (b) syllable structure (closed vs. open), and (c) vowel position within the word (final syllable vs. non-final syllable).

3.2.3.2 Vowel production at different speech rates

In Korean, epenthetic /ɨ/ and /i/ occur in different phonological environments. While epenthetic /i/ occurs only after an English post-alveolar consonant in open syllables, epenthetic /ɨ/ can occur elsewhere, either in open or closed syllables. Therefore, different linguistic factors must be considered when designing the English loanword stimuli for epenthetic /ɨ/ and /i/.

Both English loanword and Korean lexical stimuli are actual words listed in either the Standard Korean Language Dictionary (The National Institute of Korean Language 2024)[6] or in Naver Dictionary.[7] For epenthetic /ɨ/, the controls for passage-level read speech in §3.2.3.1 were applied: (a) preceding consonants with different places of articulation, (b) syllable structure (closed vs. open), and (c) vowel position within a word (final syllable vs. non-final syllable).

Next, for epenthetic /i/, the following linguistic factors were used to control the English loanword stimuli. Since epenthetic /i/ is used only in open syllables at the end of a word, all syllables with epenthetic /i/ in the English loanword stimuli are open and occur in the final syllable of a word. Even though epenthetic /i/ occurs after the English post-alveolar consonants /ʒ/, /ʃ/, /ʤ/, or /ʧ/ at the end of a word (Ministry of Education 2017), epenthetic [y] which sounds more like [wi] is often used with English words ending in /ʃ/. For example, epenthetic [y] is used after an English /ʃ/ such as in advertisement signs and business names (Hwang 2006). Thus, some native Korean speakers may possibly use epenthetic [y] when producing these English loanwords. Due to this variability, /ʃ/ and its voiced counterpart /ʒ/ were excluded from the English loanword stimuli. Thus, the preceding consonants of epenthetic /i/ are limited to English /tʃ/ or /ʤ/ (e.g., *match* [mætʃʰi], *badge* [pætʃi]). Lexical /i/ in the Korean stimuli was controlled using the exact same factors.

In the normal speech rate experiment, all stimuli were presented in the following Korean carrier

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[6] https://stdict.korean.go.kr/main/main.do
[7] https://dict.naver.com/

sentence.

(3.1) 우리는 각각 ___X___ 발음을 하고 있습니다.

[ulinɨn kakkak ___X___ palɨmɨl hako isɨmnita]

'We are individually pronouncing X.'

As shown in the carrier sentence (3.1), the stop consonants /k/ and /p/ respectively preceded and followed each stimulus X to facilitate its extraction from the carrier sentence (Harriet & Blumstein 1993). In this experiment, all stimuli (as listed in Appendices C and D) were written in English to reduce bias from Korean orthography. In the fast speech rate experiment, the same stimuli from Appendices C and D, which were used in the normal speech rate experiment, were also used.

3.2.4 Data labeling and extraction

Text transcriptions were made manually based on audio files from all production experiments, and the Korean forced alignment tool (Yoon 2021) was used to segment audio files into words and phonemes based on text transcriptions. The alignment results from the alignment tool were shown in Text Grid files in Praat (Boersma & Weenink 2024).

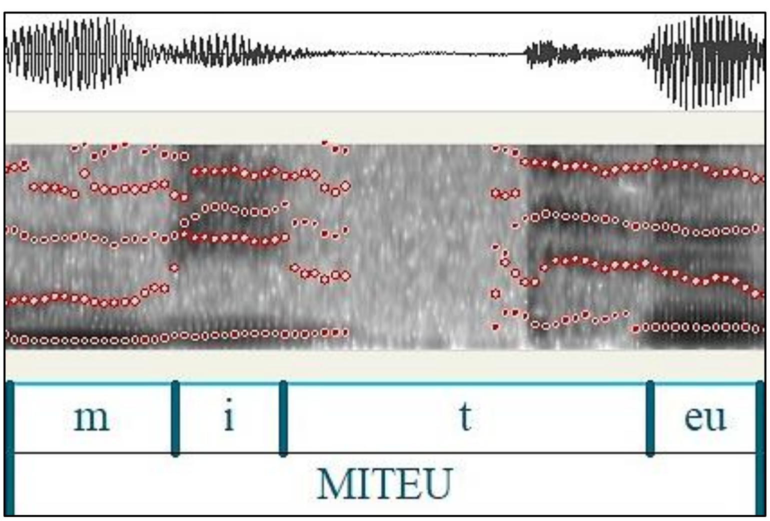

Figure 3.1 Spectrogram of *meat* [mit^{h}ɨ]

As seen in Figure 3.1 the alignment result had two tiers for 'word' and 'phoneme' levels. To find and correct alignment errors of the automatic alignment process, all alignments were checked manually based on the following measurement criteria: (a) the starting point of target vowel is the onset of F2 and (b) the end point of target vowel is the offset of F2 or the point that the spectrogram and waveform exhibited a sudden change resulting from the following consonant (Renwick 2012).

Devoiced vowels with no typical vowel formants were found after voiceless consonants or between voiceless consonants and they were excluded. After all alignments were manually checked, a Praat script was used to extract vowel durations and midpoints for the first three formant values of the target vowels. In the Praat script, three formants were detected with a ceiling of 5000 Hz for male speakers and 5500 Hz for female speakers. After extracting phonetic features from the Praat TextGrids into an Excel file, the following information was added: participant number, gender (female vs. male), speech rate (fast vs. normal), language origin (English vs. Korean), place of articulation of the consonant preceding the target vowel (alveolar vs. bilabial vs. velar), vowel position within the word (final vs. non-final), and syllable structure (closed vs. open). All revised Excel files from each participant were then combined into a single Excel file.

3.3 Results

3.3.1 Vowel production in passage-level read speech

In the experiment on reading passages, 36 epenthetic /ɨ/ and 36 lexical /ɨ/ stimuli were collected from each participant, resulting in 2,160 stimuli collected from 30 participants. 5 stimuli with epenthetic /ɨ/, and 3 stimuli with lexical /ɨ/ were excluded due to devoicing, so 2,152 stimuli were used for statistical analysis.

Table 3.2 Total number of stimuli for passage-level read speech by gender

Vowel type	Epenthetic /ɨ/		Lexical /ɨ/		Total
	Female	Male	Female	Male	
	538	537	539	538	
Total	1,075		1,077		2,152

3.3.1.1 F1 and F2 formant values

72 stimuli were collected from each participant, and a total of 2,152 stimuli excluding devoiced stimuli were used for statistical analysis.

Figure 3.2 Mean F1 and F2 values (Hz) of epenthetic /ɨ/ and lexical /ɨ/ for 15 female speakers in passage-level read speech

Figure 3.3 Mean F1 and F2 values (Hz) of epenthetic /ɨ/ and lexical /ɨ/ for 15 male speakers in passage-level read speech

In Figures 3.2 and 3.3, each data point represents the overall mean F1 and F2 values for 15 female speakers and 15 male speakers, respectively.

Table 3.3 Mean F1 and F2 values (Hz) with SD of epenthetic /ɨ/ and lexical /ɨ/ for all speakers in passage-level read speech

	Female		Male	
	F1	F2	F1	F2
Epenthetic /ɨ/	447.31 (28.67)	1733.02 (129.15)	381.47 (25.71)	1425.95 (26.59)
Lexical /ɨ/	440.82 (27.59)	1729.94 (121.37)	375.95 (133.73)	1409.26 (126.09)

As shown in Table 3.3, there are formant differences between epenthetic /ɨ/ and lexical /ɨ/ in both genders. A statistical analysis was performed to assess whether the observed differences in mean F1 and F2 formant values between epenthetic /ɨ/ and lexical /ɨ/ were statistically significant.

A mixed-effects regression analysis was conducted using the lmer() function from the lme4 package (Bates et al. 2024) in R (R Core Team 2024). Based on ANOVA comparisons, the optimal model was selected for F1 and F2 formant values. The best-fitting model included fixed effects for gender (female vs. male), place of articulation (alveolar vs. bilabial vs. velar), and origin (epenthetic vs. lexical), with subject and word as a random effect.

Table 3.4 Results for F1 and F2 of epenthetic /ɨ/ and lexical /ɨ/ in passage-level read speech

F1	Estimate	Std. Error	t-value	Pr(>| t |)
(Intercept)	439.7823	11.1079	39.5918	<0.0001 ***
Gender Male	−59.0432	27.4874	−2.1481	<0.0001 ***
Place Alveolar	−18.9011	10.0293	−1.8846	0.0698
Place Bilabial	10.1831	15.6129	0.6522	0.5145
Origin Korean	−3.5482	7.1061	−0.4993	0.6191
F2	**Estimate**	**Std. Error**	**t-value**	**Pr (>| t |)**
(Intercept)	1738.6578	106.2207	16.3684	<0.0001 ***
Gender Male	−314.3204	33.0969	−9.4971	<0.0001 ***
Place Alveolar	130.1939	30.8424	4.2213	<0.0001 ***
Place Bilabial	−49.5814	17.8699	−2.7746	0.0055 **
Origin Korean	−4.5275	33.0968	−0.1368	0.8921

In Table 3.4, no significant differences were observed between the F1 and F2 formant values of epenthetic /ɨ/ and lexical /ɨ/ (F1: $p = 0.6191$; F2: $p = 0.8921$). However, gender had a significant effect on both F1 and F2 formant values with male speakers producing lower formants compared to female speakers (F1: $p < 0.0001$; F2: < 0.0001). Additionally, the place of articulation influenced F2 formant values. F2 increased when the preceding consonant was alveolar ($p < 0.0001$) and decreased when it was bilabial ($p = 0.0055$). To determine whether F2 differences between epenthetic /ɨ/ and lexical /ɨ/ exist depending on the place of articulation, Tukey's pairwise comparisons from the emmeans package (Lenth 2024) were conducted in R (R Core Team 2024).

Table 3.5 Tukey's pairwise comparisons of F2 across places of articulation in passage-level read speech

Female	Place	Comparison	Estimate	Std. Error	t-value	Pr (>| t |)
	Alveolar	Epenthetic – Lexical	9.2933	5.5579	1.6721	0.0983
	Velar	Epenthetic – Lexical	3.5382	4.1402	0.8546	0.3961
	Bilabial	Epenthetic – Lexical	12.1026	8.2375	1.4692	0.1458
Male	**Place**	**Comparison**	**Estimate**	**Std. Error**	**t -value**	**Pr (>| t |)**
	Alveolar	Epenthetic – Lexical	11.9415	8.6376	1.3825	0.1684
	Velar	Epenthetic – Lexical	9.2191	5.3216	1.7324	0.0867
	Bilabial	Epenthetic – Lexical	−7.3247	6.0157	−1.2176	0.2289

The results showed that female speakers produced a higher F2 for epenthetic /ɨ/ compared to lexical /ɨ/

across all places of articulation. For male speakers, epenthetic /ɨ/ had a higher F2 than lexical /ɨ/ with alveolar or velar consonants and a lower F2 with bilabial consonants. However, none of these differences were statistically significant for either females (alveolar: $p = 0.0983$; velar: $p = 0.3961$; bilabial: $p = 0.1458$) or males (alveolar: $p = 0.1684$; velar: $p = 0.0867$; bilabial: $p = 0.2289$). This indicates that the F2 formant values of epenthetic /ɨ/ and lexical /ɨ/ behave similarly across alveolar, velar, and bilabial contexts.

3.3.1.2 Vowel durations

Figure 3.4 and Table 3.7 show the vowel duration of epenthetic /ɨ/ and lexical /ɨ/ for all speakers in passage-level read speech.

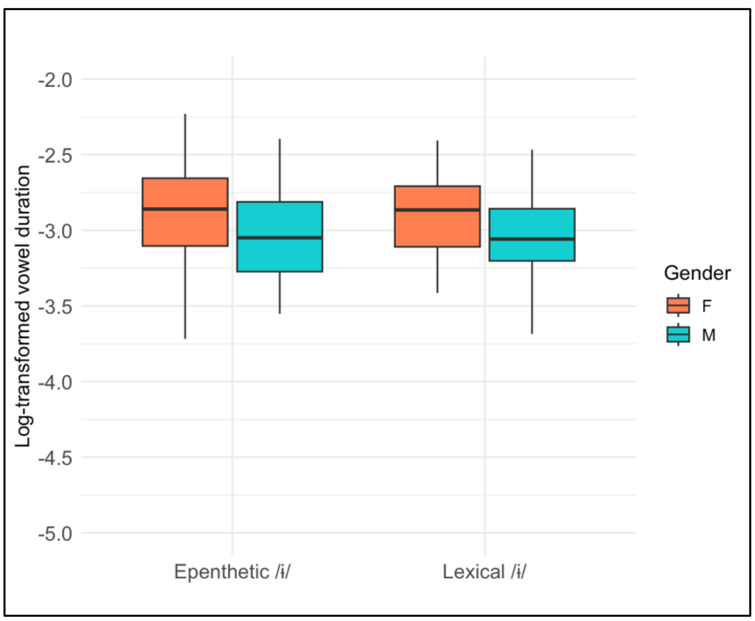

Figure 3.4 Vowel durations (log-transformed) of lexical /ɨ/ and epenthetic /ɨ/ for all speakers in passage-level read speech

Table 3.6 Mean durations (s) with SD of epenthetic /ɨ/ and lexical /ɨ/ for all speakers in passage-level read speech

Epenthetic /ɨ/		Lexical /ɨ/	
Female	Male	Female	Male
0.0574 (0.0178)	0.0499 (0.0153)	0.0568 (0.0136)	0.0501(0.0149)

Table 3.6 shows the mean durations of epenthetic /ɨ/ and lexical /ɨ/ in passage-level read speech. For female speakers, epenthetic /ɨ/ has a longer duration than lexical /ɨ/, while for male speakers, lexical /ɨ/ has a longer duration than epenthetic /ɨ/. Additionally, male speakers produced both epenthetic /ɨ/ and lexical /ɨ/ with shorter durations compared to female speakers. To investigate these differences statistically mixed-effects modeling was fitted using the lmer() function. The most suitable model had fixed effects for gender (female vs. male), origin (epenthetic vs. lexical), vowel position within the word (final vs. non-final), and syllable structure (closed vs. open) with subject and word as random effects.

Table 3.7 Results for durations of epenthetic /ɨ/ and lexical /ɨ/ in passage-level read speech

	Estimate	Std. Error	t-value	Pr (>| t |)
(Intercept)	0.0565	0.0032	17.6562	<0.0001 ***
Gender Male	−0.0053	0.0024	−2.2083	0.0412 *
Origin Korean	−0.0018	0.0015	−1.2001	0.2318
Position Final	0.0081	0.0031	2.6129	0.0091 **
Structure Open	0.0107	0.0028	3.8214	0.0019 **

As shown in Table 3.7, the durations of epenthetic /ɨ/ and lexical /ɨ/ are not significantly different (p = 0.2318). However, duration is influenced by gender (p = 0.0412), vowel position within the word (p = 0.0091), and syllable structure (p = 0.0019). To further examine the specific effects on epenthetic /ɨ/ and lexical /ɨ/, Tukey's pairwise comparisons were conducted. The results showed that both epenthetic /ɨ/ and lexical /ɨ/ were shorter under the following conditions: (a) when produced by male speakers (epenthetic /ɨ/: p = 0.0435; lexical /ɨ/: p = 0.0261), (b) when occurring in the non-final position (epenthetic /ɨ/: p = 0.0062; lexical /ɨ/: p = 0.0031), and (c) when occurring in closed syllables (epenthetic /ɨ/: p = 0.0014; lexical /ɨ/: p = 0.0009). A full account of the statistical results is included in Table E1 in Appendix E.

This chapter reports statistical findings in passage-level read speech, showing that: (a) the F1 and F2 formant values of epenthetic /ɨ/ are equivalent to those of lexical /ɨ/ across all places of articulation of the preceding consonant, and (b) the duration of epenthetic /ɨ/ was comparable to that of lexical /ɨ/ across different genders, vowel position within the word, and syllable structures.

3.3.2 Vowel production at different speech rates

3.3.2.1 Overview of epenthetic and lexical vowels at the normal speech rate

In the production experiment conducted at the normal speech rate, 112 stimuli were used: 36 epenthetic /ɨ/ stimuli, 20 epenthetic /i/ stimuli, 36 lexical /ɨ/ stimuli, and 20 lexical /i/ stimuli. Participants were asked to read each stimulus twice, resulting in 224 stimuli collected from each participant, and a total of 6,720 stimuli were collected from 30 participants. However, 6 stimuli with epenthetic /ɨ/, 9 stimuli with epenthetic /i/, and 5 stimuli with lexical /ɨ/, and 6 stimuli with lexical /i/, were devoiced. As a result, 6,694 stimuli were used for statistical analysis, as shown in Table 3.8.

Table 3.8 Number of analyzed epenthetic and lexical vowels at normal speech rate

	Epenthetic /ɨ/		Lexical /ɨ/		
	Female	Male	Female	Male	
	1,078	1,076	1,077	1,078	
Total	2,154		2,155		4,309
	Epenthetic /i/		Lexical /i/		
	Female	Male	Female	Male	
	595	596	599	595	
Total	1,191		1,194		2,385

Figures 3.5 and 3.6 present the mean F1 and F2 values for female and male speakers, respectively, at the normal speech rate. Each data point represents the mean F1 and F2 values for each speaker.

Figure 3.5 Mean F1 and F2 values (Hz) of epenthetic and lexical vowels for 15 female speakers at normal speech rate

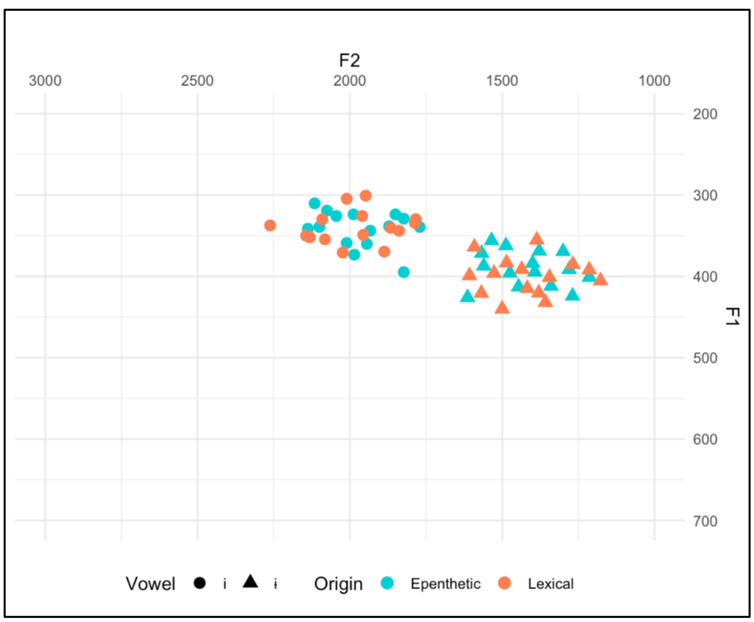

Figure 3.6 Mean F1 and F2 values (Hz) of epenthetic and lexical vowels for 15 male speakers at normal speech rate

Figures 3.7 and 3.8 and Table 3.9 show the overall mean F1 and F2 values of epenthetic and lexical vowels for 15 female and 15 male speakers. In Figures 3.7 and 3.8, each data point indicates the overall mean F1 and F2 values for groups of 15 female and 15 male speakers, respectively.

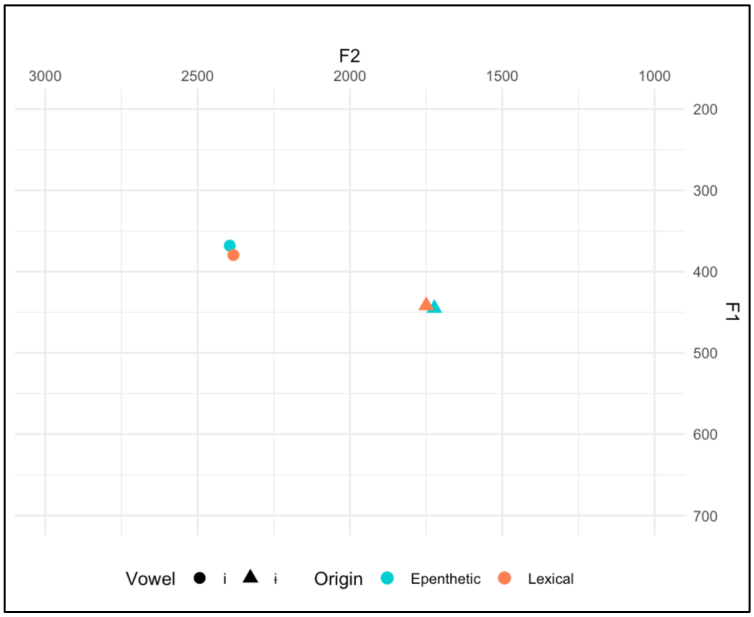

Figure 3.7 Overall mean F1 and F2 values (Hz) of epenthetic and lexical vowels for 15 female speakers at normal speech rate

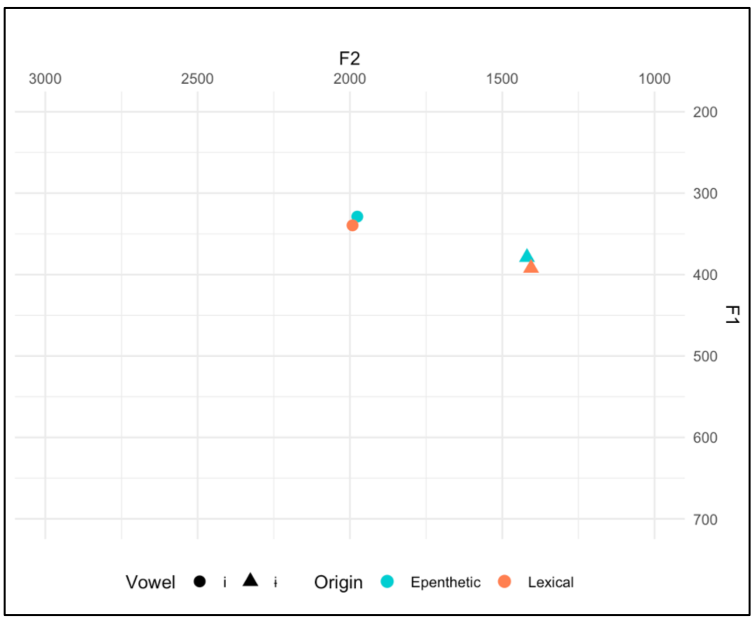

Figure 3.8 Overall mean F1 and F2 values (Hz) of epenthetic and lexical vowels for 15 male speakers at normal speech rate

Table 3.9 Overall mean F1 and F2 values (Hz) with SD of epenthetic and lexical vowels for all speakers at normal speech rate

	Epenthetic /ɨ/		Lexical /ɨ/	
	Female	Male	Female	Male
F1	445.01 (35.05)	378.74 (30.98)	441.79 (33.59)	392.07 (30.28)
F2	1722.85 (124.82)	1418.74 (115.63)	1749.42 (118.14)	1405.32 (116.35)
	Epenthetic /i/		Lexical /i/	
	Female	Male	Female	Male
F1	368.01 (34.23)	328.76 (36.34)	379.59 (35.81)	339.51 (28.67)
F2	2394.43 (159.17)	1975.82 (139.61)	2382.64 (159.75)	1991.38 (135.85)

In Table 3.9, compared to those of epenthetic /i/ and lexical /i/, the mean F1 values of epenthetic /ɨ/ and lexical /ɨ/ are higher, and the mean F2 values of epenthetic /ɨ/ and lexical /ɨ/ are lower in both genders. In Korean, even though both /i/ and /ɨ/ are classified as high vowels, /ɨ/ is typically produced with a slightly lower articulation (Son 2017). In addition, /ɨ/ is a central vowel with slight tongue retraction, whereas /i/ is a front vowel. Therefore, /ɨ/ has a higher F1 value and a lower F2 value than /i/ in Korean.

Next, Figures 3.9 and 3.10 and Table 3.10 show the mean durations for all vowels at the normal speech rate.

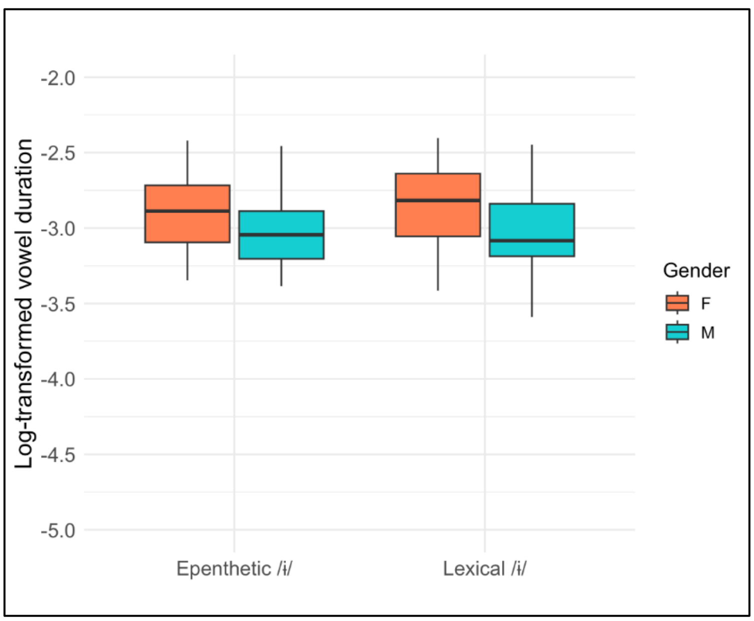

Figure 3.9 Vowel durations (log-transformed) of epenthetic /ɨ/ and lexical /ɨ/ for all speakers at normal speech rate

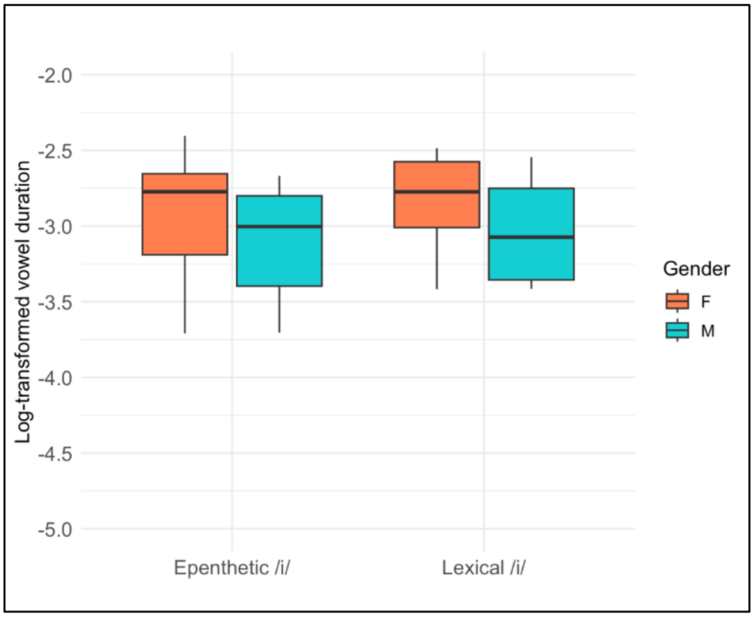

Figure 3.10 Vowel durations (log-transformed) of epenthetic /i/ and lexical /i/ for all speakers at normal speech rate

Table 3.10 Overall mean durations (s) with SD of epenthetic and lexical vowels for all speakers at normal speech rate

Normal rate	Epenthetic /ɨ/		Lexical /ɨ/	
	Female	Male	Female	Male
	0.0579 (0.0146)	0.0509 (0.0139)	0.0591 (0.0158)	0.0513 (0.0163)
Normal rate	Epenthetic /i/		Lexical /i/	
	Female	Male	Female	Male
	0.0585 (0.0192)	0.0517 (0.0174)	0.0599 (0.0184)	0.0507 (0.0166)

To investigate whether the /ɨ/ and /i/ types exhibit durational differences, a t-test was conducted for comparisons at the normal speech rate. For female speakers, the t-test revealed no significant durational differences between epenthetic /ɨ/ and epenthetic /i/ (p = 0.3055) or between lexical /ɨ/ and lexical /i/ (p = 0.0967). Similarly, for male speakers, there were no significant durational differences between epenthetic /ɨ/ and epenthetic /i/ (p = 0.1637) or between lexical /ɨ/ and lexical /i/ (p = 0.1735). These results indicate that there are no statistically significant durational differences between /ɨ/ and /i/ types at the normal speech rate.

3.3.2.1.1 Epenthetic /ɨ/ and lexical /ɨ/ at the normal speech rate

A total of 4,309 vowels were analyzed in normal speech.

Table 3.11 Number of analyzed epenthetic /ɨ/ and lexical /ɨ/ at normal speech rate

	Epenthetic /ɨ/		Lexical /ɨ/		Total
	Female	Male	Female	Male	
	1,078	1,076	1,077	1,078	
Total	2,154		2,155		4,309

As indicated in Table 3.11, this analysis included 2,154 epenthetic /ɨ/ and 2,155 lexical /ɨ/ cases. Figures 3.11 and 3.12 display the mean F1 and F2 values for 15 female speakers and 15 male speakers, respectively. In these figures, each data point represents the average F1 and F2 values for each speaker.

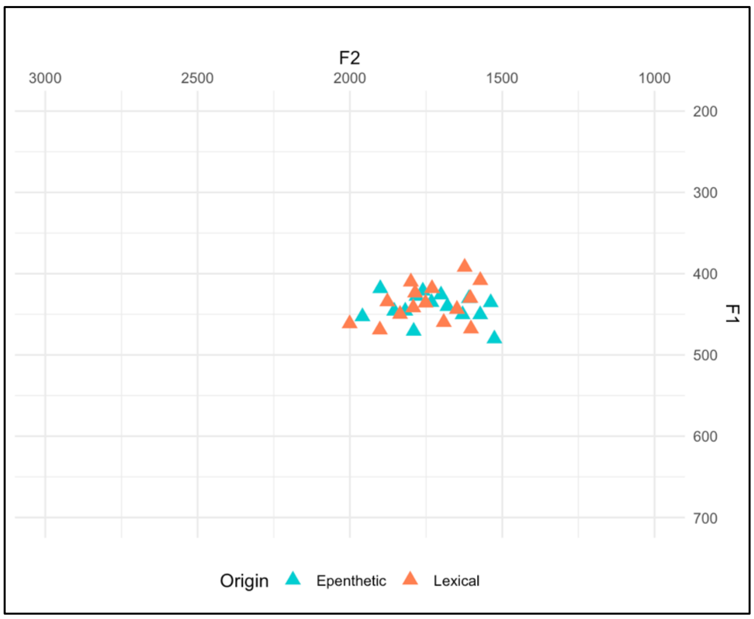

Figure 3.11 Mean F1 and F2 values (Hz) of epenthetic /ɨ/ and lexical /ɨ/ for 15 female speakers at normal speech rate

Figure 3.12 Mean F1 and F2 values (Hz) of epenthetic /ɨ/ and lexical /ɨ/ for 15 male speakers at normal speech rate

Table 3.12 Mean F1 and F2 values (Hz) with SD of epenthetic /ɨ/ and lexical /ɨ/ for all speakers at normal speech rate

	Epenthetic /ɨ/		Lexical /ɨ/	
	Female	Male	Female	Male
F1	445.01 (35.05)	378.74 (30.98)	441.79 (33.59)	392.07 (30.28)
F2	1722.85 (124.82)	1418.74 (115.63)	1749.42 (118.14)	1405.32 (116.35)

Table 3.13 shows that for female speakers, epenthetic /ɨ/ had a higher F1 and a lower F2 than lexical /ɨ/. For male speakers, epenthetic /ɨ/ had a lower F1 and a higher F2 than lexical /ɨ/. To determine if the observed differences in mean F1 and F2 values between epenthetic /ɨ/ and lexical /ɨ/ statistically significant, a mixed-effects regression analysis was conducted using the lmer() function. The best-fitting model was chosen based on ANOVA comparisons for the F1 and F2 formant values. The best model included gender (female vs. male), place of articulation (alveolar vs. bilabial vs. velar), and origin (epenthetic vs. lexical) as fixed effects, with subject and word as random effects.

Table 3.13 Results for F1 and F2 of epenthetic /ɨ/ and lexical /ɨ/ at normal speech rate

F1	Estimate	Std. Error	t-value	Pr (>| t |)
(Intercept)	451.0063	61.1072	7.3805	<0.0001 ***
Gender Male	−61.1987	43.4875	−1.4072	0.0359 *
Place Alveolar	23.3241	19.4996	1.1961	0.0688
Place Bilabial	−16.1649	16. 9483	−0.9537	0.3402
Origin Korean	2.0734	11.3419	0.1820	0.8524
F2	**Estimate**	**Std. Error**	**t-value**	**Pr (>| t |)**
(Intercept)	1649.4215	106.2247	15.5276	<0.0001 ***
Gender Male	−344.1029	37.0853	−9.2786	<0.0001 ***
Place Alveolar	142.7627	59.2928	2.4077	0.0167 *
Place Bilabial	−37.4918	17.8692	−2.0981	0.0362 *
Origin Korean	6.5812	29.5644	0.2226	0.7043

In Table 3.13, F1 and F2 formant values of epenthetic /ɨ/ and lexical /ɨ/ were not significantly different from each other (F1: $p = 0.8524$; F2: $p = 0.7043$). On the other hand, gender affected both F1 and F2 formant values. Male speakers had the lower F1 and F2 than female speakers (F1: $p = 0.0359$; F2: $p < 0.0001$). Also, the place of articulation affected F2 values. Specifically, F2 values were raised when the preceding consonant was alveolar ($p = 0.0167$), but they were lowered when it was bilabial ($p = 0.0362$). To investigate whether there are F2 differences between epenthetic /ɨ/ and lexical /ɨ/ depending on the place of articulation, Tukey's pairwise comparisons were performed.

Table 3.14 Tukey's pairwise comparisons of F2 across places of articulation at normal speech rate

Female	Place	Comparison	Estimate	Std. Error	t-value	Pr (>|t|)
	Alveolar	Epenthetic – Lexical	–12.0091	5.5546	–2.1621	0.1604
	Velar	Epenthetic – Lexical	1.1844	0.9908	1.1954	0.8527
	Bilabial	Epenthetic – Lexical	–19.8713	8.7460	–2.2720	0.3841
Male	**Place**	**Comparison**	**Estimate**	**Std. Error**	**t-value**	**Pr (>|t|)**
	Alveolar	Epenthetic – Lexical	9.2517	5.9454	1.5561	0.0925
	Velar	Epenthetic – Lexical	10.4934	6.4378	1.6299	0.1064
	Bilabial	Epenthetic – Lexical	5.5352	4.4963	1.2311	0.2186

In Table 3.14, for female speakers, epenthetic /ɨ/ had a lower F2 than lexical /ɨ/ when the preceding consonant was alveolar or bilabial, and a higher F2 than lexical /ɨ/ when the preceding consonant was velar. For male speakers, epenthetic /ɨ/ had a higher F2 than lexical /ɨ/ across all places of articulation.

However, these differences were not statistically significant for both females (alveolar: $p = 0.1604$; velar: $p = 0.8527$; bilabial: $p = 0.3841$) and males (alveolar: $p = 0.0925$; velar: $p = 0.1064$; bilabial: $p = 0.2186$). This means that F2 formant values for epenthetic /ɨ/ and lexical /ɨ/ do not differ significantly within each place of articulation.

Next, Table 3.15 shows the mean duration of epenthetic /ɨ/ and lexical /ɨ/ and Table 3.16 shows the statistical results on their durations. The best model for duration based on the lmer() function included fixed effects for gender (female vs. male), origin (epenthetic vs. lexical), vowel position within a word (final vs. non-final), syllable structure (closed vs. open), and speech rate (fast vs. normal) with subject and word as random effects.

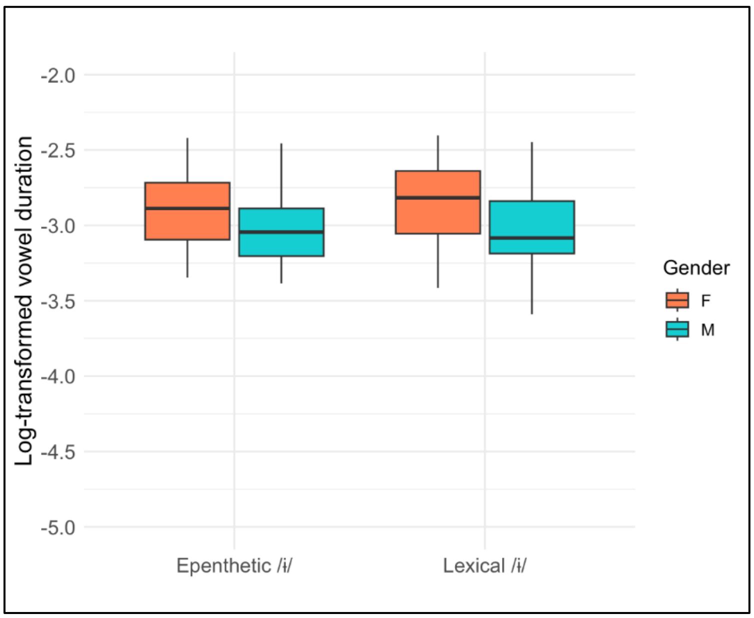

Figure 3.13 Vowel durations (log-transformed) of epenthetic /ɨ/ and lexical /ɨ/ for all speakers at normal speech rate

Table 3.15 Mean durations (s) with SD of epenthetic /ɨ/ and lexical /ɨ/ for all speakers at normal speech rate

Normal rate	Epenthetic /ɨ/		Lexical /ɨ/	
	Female	Male	Female	Male
	0.0579 (0.0146)	0.0509 (0.0139)	0.0591 (0.0158)	0.0513 (0.0163)

Table 3.16 Results of the mixed-effects model for durations of epenthetic /ɨ/ and lexical /ɨ/

	Estimate	Std. Error	t-value	Pr (>| t |)
(Intercept)	0.0573	0.0041	13.9756	<0.0001 ***
Gender Male	−0.0072	0.0032	−2.2499	0.0476 *
Origin Korean	0.0014	0.0011	1.2726	0.3276
Position Final	0.0071	0.0029	2.4483	0.0198 *
Structure Open	0.0016	0.0015	1.0667	0.3192
Rate Fast	−0.0315	0.0197	−1.5990	0.0058 **

As shown in Table 3.16, the best mixed-effects model had speech rate as a fixed effect, along with gender, origin, vowel position, and syllable structure. This suggests that the model reflects the overall influence of these fixed effects across both normal and fast speech conditions, rather than focusing solely on the normal rate. To analyze the specific effects at the normal speech rate, Tukey's pairwise comparisons were performed for the normal speech rate based on the best mixed-effects model. The result showed that durations of epenthetic /ɨ/ and lexical /ɨ/ at the normal speech rate were not significantly different from each other (p = 0.9301). Detailed statistical results are provided in Table E2 in Appendix E.

In addition, to investigate whether epenthetic /ɨ/ and lexical /ɨ/ behave similarly depending on other factors at normal speech rate, Tukey's pairwise comparisons were conducted.

Table 3.17 Tukey's pairwise comparisons of durations by gender, vowel position, and syllable structure at normal speech rate

Origin	Comparison (gender)	Estimate	Std. Error	t-value	Pr (>|t|)
Epenthetic /ɨ/	Male – Female	−0.0064	0.0028	−2.2857	0.0301 *
Lexical /ɨ/	Male – Female	−0.0076	0.0031	−2.4516	0.0225 *
Origin	Comparison (vowel position)	Estimate	Std. Error	t-value	Pr (>|t|)
Epenthetic /ɨ/	Non final – Final	−0.0119	0.0044	−2.7045	0.0124 *
Lexical /ɨ/	Non final – Final	−0.0091	0.0043	−2.1163	0.0388 *
Origin	Comparison (syllable structure)	Estimate	Std. Error	t-value	Pr (>|t|)
Epenthetic /ɨ/	Open – Closed	0.0092	0.0043	2.1395	0.0383 *
Lexical /ɨ/	Open – Closed	0.0088	0.0038	2.3158	0.0169 *

In Table 3.17, both epenthetic /ɨ/ and lexical /ɨ/ at the normal speech rate were short when (a) they were produced by male speakers (epenthetic /ɨ/: p = 0.0301; lexical /ɨ/: p = 0.0225), (b) they occurred in the non-final word position (epenthetic /ɨ/: p = 0.0124; lexical /ɨ/: p = 0.0388), and (c) they occurred in the closed syllable (epenthetic /ɨ/: p = 0.0383; lexical /ɨ/: p = 0.0169).

In this section, the statistical results at the normal speech rate confirmed that: (a) the F1 and F2 formant values of epenthetic /ɨ/ were the same as those of lexical /ɨ/ when positioned before consonants with different places of articulation in both genders, and (b) the duration of epenthetic /ɨ/ matched that of lexical /ɨ/ across genders, vowel positions and syllable structures.

3.3.2.1.2 Epenthetic /i/ and lexical /i/ at the normal speech rate

In total, 2,385 vowels were examined in normal speech.

Table 3.18 Number of analyzed epenthetic /i/ and lexical /i/ at normal speech rate

	Epenthetic /i/		Lexical /i/		
	Female	Male	Female	Male	
	595	596	599	595	
Total	1,191		1,194		2,385

As shown in Table 3.18, a total of 1,191 epenthetic /i/ and 1,194 lexical /i/ were analyzed in normal speech. Figures 3.14 and 3.15 illustrate the mean F1 and F2 values for 15 female and 15 male speakers, respectively, with each data point representing the average F1 and F2 values for an individual speaker.

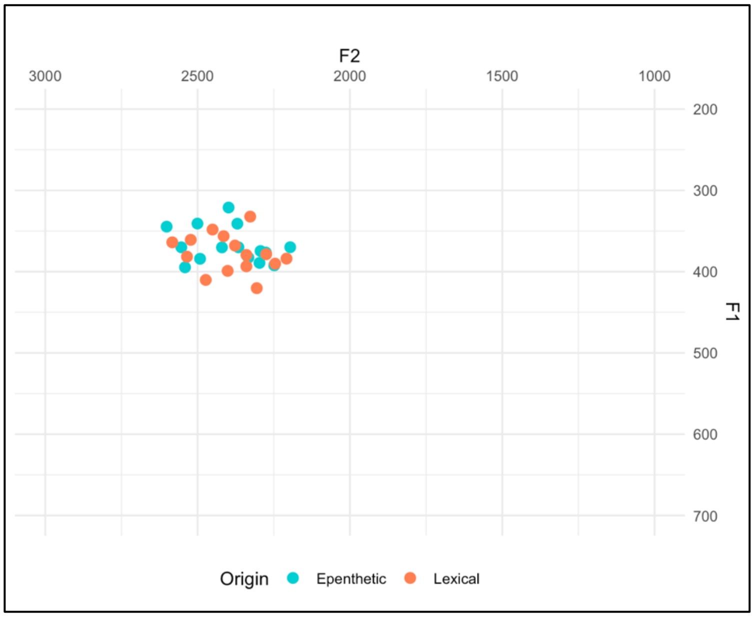

Figure 3.14 Mean F1 and F2 values (Hz) of epenthetic /i/ and lexical /i/ for 15 female speakers at normal speech rate

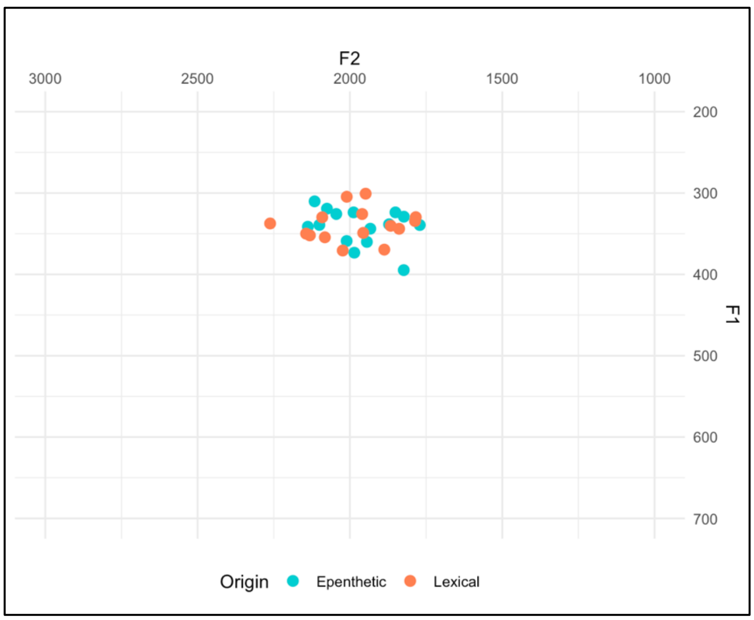

Figure 3.15 Mean F1 and F2 values (Hz) of epenthetic /i/ and lexical /i/ for 15 male speakers at normal speech rate

Table 3.19 Mean F1 and F2 values (Hz) with SD of epenthetic /i/ and lexical /i/ for all speakers at normal speech rate

	Epenthetic /i/		Lexical /i/	
	Female	Male	Female	Male
F1	368.01 (34.23)	328.76 (36.34)	379.59 (35.81)	339.51 (28.67)
F2	2394.43 (159.17)	1975.82 (139.61)	2382.64 (159.75)	1991.38 (135.85)

Table 3.19 indicates that among female speakers, epenthetic /i/ exhibited a lower F1 and a higher F2 compared to lexical /i/. For male speakers, epenthetic /i/ showed a lower F1 and a lower F2 than lexical /i/. To assess whether these observed differences in mean F1 and F2 values between epenthetic and lexical /i/ were statistically significant, a statistical analysis was performed. The models were based on the lmer() function, and the best model was selected based on ANOVA comparisons for F1, F2, and duration. This model included gender (female vs. male), origin (epenthetic vs. lexical), and speech rate (fast vs. normal) as fixed effects, with subject and word as random effects.

Table 3.20 Results for F1 and F2 of epenthetic /i/ and lexical /i/

F1	Estimate	Std. Error	t-value	Pr (>| t |)
(Intercept)	378.6012	8.1051	46.7115	<0.0001 ***
Gender Male	−40.0083	10.3137	−3.8791	<0.0001 ***
Origin Korean	11.1726	17.6256	0.6339	0.5262
Rate Fast	47.6917	16.4609	2.8973	0.0038 *
F2	**Estimate**	**Std. Error**	**t-value**	**Pr (>| t |)**
(Intercept)	2182.6143	35.7192	61.1048	<0.0001 ***
Gender Male	−391.2632	46.8915	−8.3440	<0.0001 ***
Origin Korean	9.8967	33.3093	0.2971	0.7671
Rate Fast	−96.3413	29.7254	−3.2411	0.0012 **

Table 3.20 indicates that the most effective mixed-effects model included speech rate as a fixed effect. That is, this model captures the combined impact of these variables across both normal and fast speech conditions, rather than isolating the normal rate. To specifically examine the effects at the normal speech rate, Tukey's pairwise comparisons were conducted for this rate alone. The results showed that the F1 and F2 values of epenthetic /i/ did not differ from those of lexical /i/ in female speakers (F1: p = 0.8181; F2: p = 0.6159) and male speakers (F1: p = 0.6199; F2: p = 0.9361). Detailed statistical results are provided in

Table E3 in Appendix E.

Next, Table 3.22 presents the mean duration of epenthetic /i/ and lexical /i/ and Table 3.23 shows statistical results for their durations.

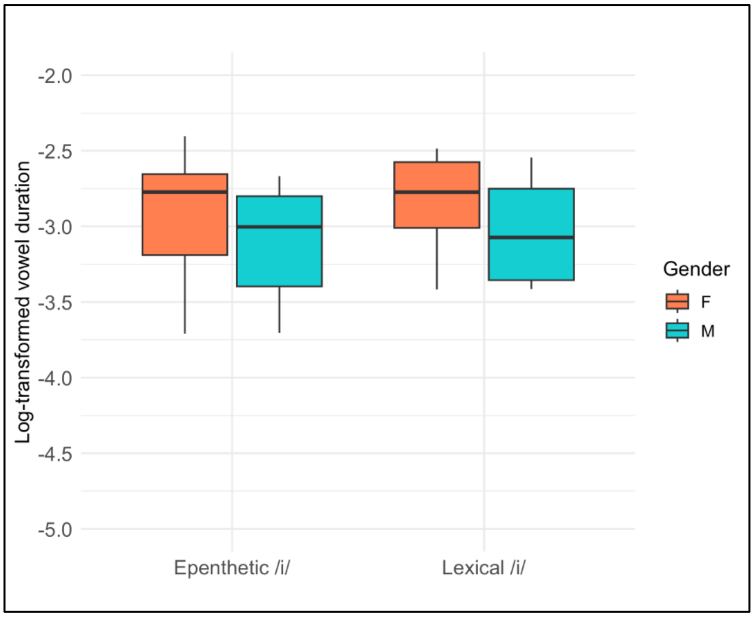

Figure 3.16 Vowel durations (log-transformed) of epenthetic /i/ and lexical /i/ for all speakers at normal speech rate

Table 3.21 Mean durations (s) with SD of epenthetic /i/ and lexical /i/ for all speakers at normal speech rate

Normal rate	Epenthetic /i/		Lexical /i/	
	Female	Male	Female	Male
	0.0585 (0.0192)	0.0517 (0.0174)	0.0599 (0.0185)	0.0507 (0.0166)

Table 3.22 Results for durations of epenthetic /i/ and lexical /i/

	Estimate	Std. Error	t-value	Pr (>| t |)
(Intercept)	0.0463	0.0157	2.9490	0.0020 **
Gender Male	−0.0079	0.0032	−2.4688	0.0372 *
Origin Korean	0.0051	0.0201	0.2537	0.8029
Rate Fast	−0.0174	0.0078	−2.2308	0.0021 **

Results in Table 3.22 show the combined impact of these variables across both normal and fast speech rates; hence, Tukey's pairwise comparisons were conducted for the normal speech rate. The result showed that durations of epenthetic /i/ and lexical /i/ at the normal speech rate were not significantly different from each other (p = 0.9640). The statistical analysis result is available in Table E4 in Appendix E. In addition, Tukey's pairwise comparisons showed that both epenthetic /i/ and lexical /i/ at the normal speech rate were short when they were produced by male speakers (epenthetic /i/: p = 0.0399; lexical /i/: p = 0.0401). Detailed statistical results are provided in Table E5 in Appendix E.

In summary, the statistical analysis showed that at the normal speech rate, the F1 and F2 values of epenthetic /i/ matched those of lexical /i/ in both genders, and male speakers produced shorter durations for both epenthetic /i/ and lexical /i/.

3.3.2.2 Overview of epenthetic and lexical vowels at the fast speech rate

A total of 9,307 stimuli were collected from 30 participants, with an average of 2.77 (female: 2.56; male: 2.98) target words read per five seconds. However, 14 stimuli with epenthetic /ɨ/, 12 stimuli with epenthetic /i/, 19 stimuli with lexical /ɨ/, and 15 stimuli with lexical /i/ were devoiced, so 9,242 stimuli were statistically analyzed in fast speech, as detailed in Table 3.23.

Table 3.23 Number of analyzed epenthetic and lexical vowels at fast speech rate

	Epenthetic /ɨ/		Lexical /ɨ/		
	Female	Male	Female	Male	
	1,386	1,595	1,375	1,599	
Total	2,981		2,974		5,955
	Epenthetic /i/		Lexical /i/		
	Female	Male	Female	Male	
	764	877	756	890	
Total	1,641		1,646		3,287

As Table 3.23 shows, 2,981 epenthetic /ɨ/, 2,974 lexical /ɨ/, 1,641 epenthetic /i/, and 1,646 lexical /i/ were analyzed in fast speech. The following Figures 3.17 and 3.18 show the average F1 and F2 values for 15 female speakers and 15 male speakers, respectively. In these figures, each data point represents the mean F1 and F2 values for an individual speaker.

Figure 3.17 Mean F1 and F2 values (Hz) of epenthetic and lexical vowels for 15 female speakers at fast speech rate

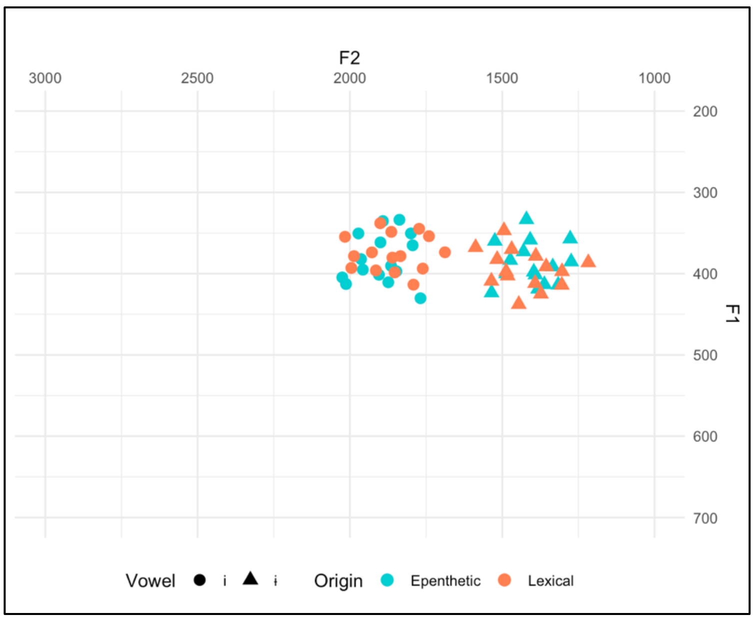

Figure 3.18 Mean F1 and F2 values (Hz) of epenthetic and lexical vowels for 15 male speakers at fast speech rate

Figures 3.19 and 3.20 and Table 3.24 present the overall mean F1 and F2 values for epenthetic and lexical vowels across 15 female and 15 male speakers. In Figures 3.19 and 3.20, each data point represents the collective mean F1 and F2 values for the groups of 15 female and 15 male speakers, respectively.

Figure 3.19 Overall mean F1 and F2 values (Hz) of epenthetic and lexical vowels for 15 female speakers at fast speech rate

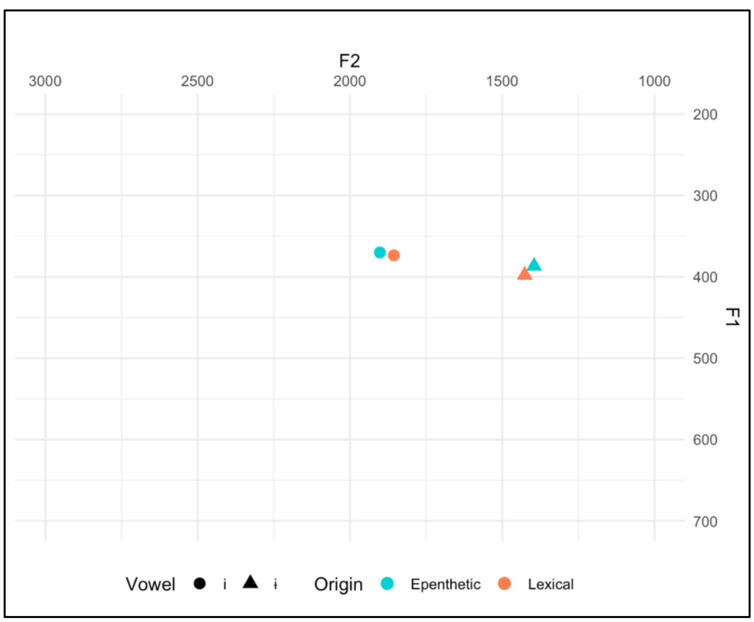

Figure 3.20 Overall mean F1 and F2 values (Hz) of epenthetic and lexical vowels for 15 male speakers at fast speech rate

Table 3.24 Overall mean F1 and F2 values (Hz) with SD of epenthetic and lexical vowels for all speakers at fast speech rate

	Epenthetic /ɨ/		Lexical /ɨ/	
	Female	Male	Female	Male
F1	459.89 (23.49)	386.74 (20.38)	462.91 (25.85)	397.73 (23.41)
F2	1725.25 (118.38)	1395.27 (102.29)	1710.54 (120.02)	1426.28 (115.82)
	Epenthetic /i/		Lexical /i/	
	Female	Male	Female	Male
F1	435.87 (31.88)	369.01 (33.04)	427.25 (35.02)	373.52 (27.48)
F2	2309.25 (123.33)	1901.63 (104.92)	2292.32 (134.49)	1872.71 (121.05)

In Table 3.24, for both genders, the F1 and F2 formant values of epenthetic /i/ and lexical /i/ exhibit greater changes compared to those of epenthetic /ɨ/ and lexical /ɨ/ at the fast speech rate. A detailed discussion of these results is provided in the following sections.

Next, Figures 3.21 and 3.22 and Table 3.25 present the mean durations for all vowels at the fast speech rate.

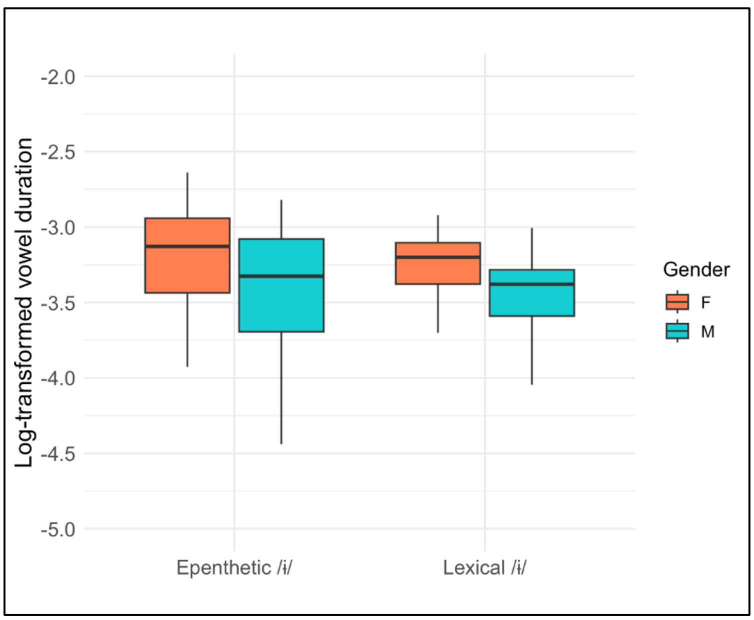

Figure 3.21 Vowel durations (log-transformed) of epenthetic /ɨ/ and lexical /ɨ/ for all speakers at fast speech rate

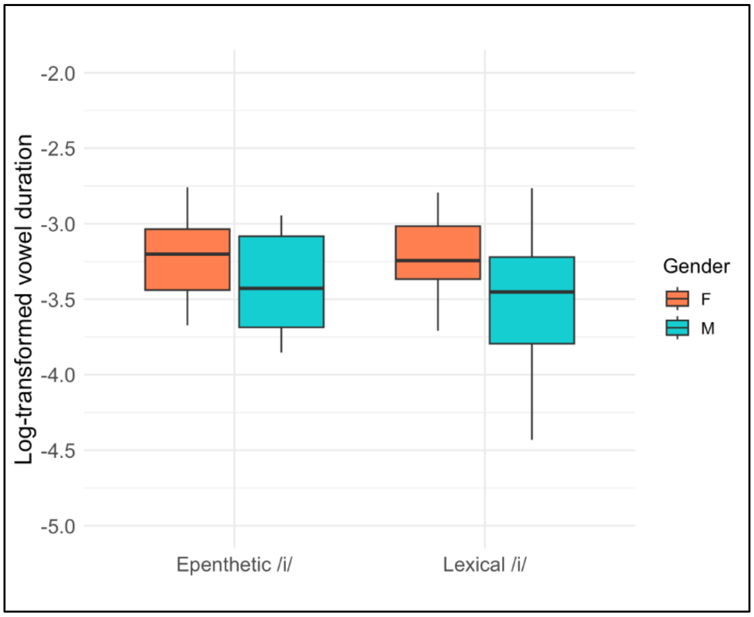

Figure 3.22 Vowel durations (log-transformed) of epenthetic /i/ and lexical /i/ for all speakers at fast speech rate

Table 3.25 Overall mean durations (s) with SD of epenthetic and lexical vowels for all speakers at fast speech rate

Fast rate	Epenthetic /ɨ/		Lexical /ɨ/	
	Female	Male	Female	Male
	0.0431 (0.0133)	0.0352 (0.0128)	0.0420 (0.0127)	0.0343 (0.0115)
Fast rate	Epenthetic /i/		Lexical /i/	
	Female	Male	Female	Male
	0.0422 (0.0117)	0.0347 (0.0111)	0.0425 (0.0106)	0.0339 (0.0129)

A t-test was performed to examine potential durational differences between the /ɨ/ and /i/ types at the fast speech rate. For female speakers, the results showed no significant durational differences between epenthetic /ɨ/ and epenthetic /i/ (p = 0.0845) or between lexical /ɨ/ and lexical /i/ (p = 0.0631). For male speakers, there were no significant differences between epenthetic /ɨ/ and epenthetic /i/ (p = 0.0623) or between lexical /ɨ/ and lexical /i/ (p = 0.0775). These results indicate that no durational differences were observed between the /ɨ/ and /i/ types at the fast speech rate.

3.3.2.2.1 Epenthetic /ɨ/ and lexical /ɨ/ at the fast speech rate

A total of 5,955 vowels were analyzed in fast speech.

Table 3.26 Number of analyzed epenthetic /ɨ/ and lexical /ɨ/ at fast speech rate

	Epenthetic /ɨ/		Lexical /ɨ/		
	Female	Male	Female	Male	
	1,386	1,595	1,375	1,599	
Total	2,981		2,974		5,955

As indicated in Table 3.26, this analysis included 2,981 epenthetic /ɨ/ and 2,974 lexical /ɨ/ cases.

Figures 3.23 and 3.24 display the mean F1 and F2 values for 15 female speakers and 15 male speakers, respectively. In these figures, each data point represents the average F1 and F2 values for each speaker.

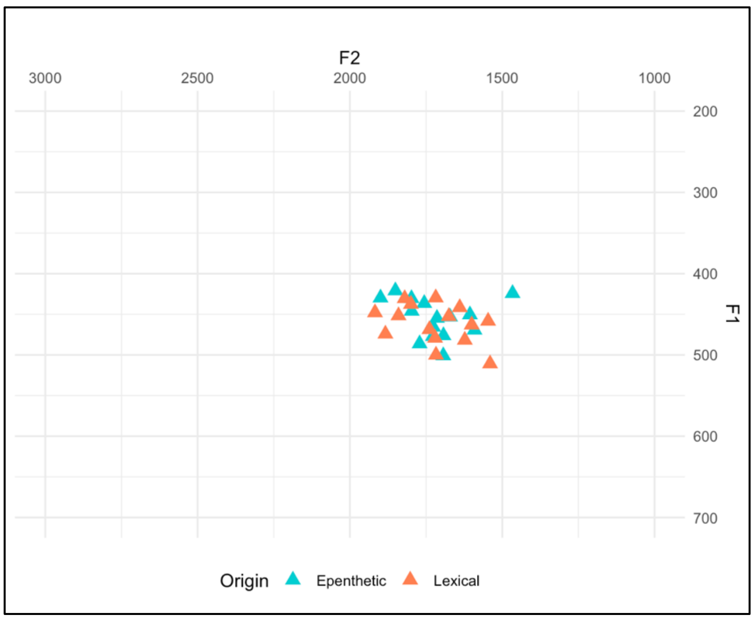

Figure 3.23 Mean F1 and F2 values (Hz) of epenthetic /ɨ/ and lexical /ɨ/ for 15 female speakers at fast speech rate

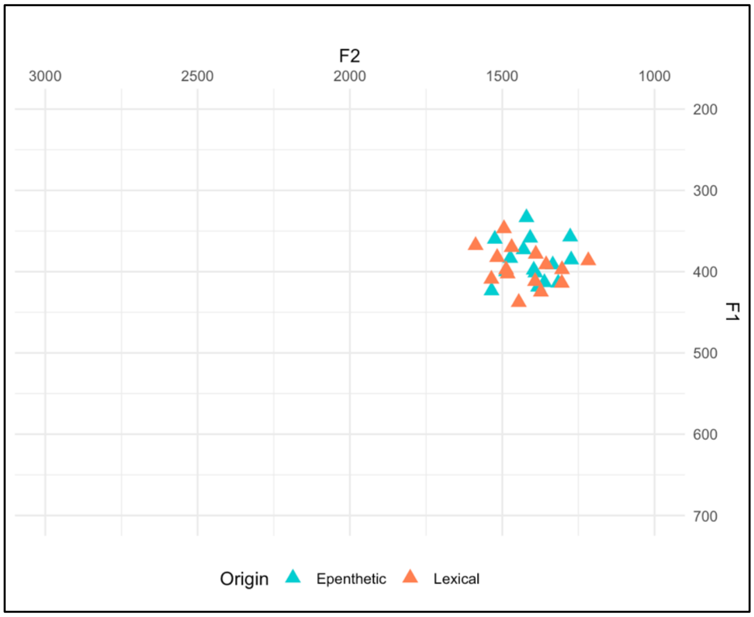

Figure 3.24 Mean F1 and F2 values (Hz) of epenthetic /ɨ/ and lexical /ɨ/ for 15 male speakers at fast speech rate

Table 3.27 Mean F1 and F2 values (Hz) with SD of epenthetic /ɨ/ and lexical /ɨ/ for all speakers at fast speech rate

	Epenthetic /ɨ/		Lexical /ɨ/	
	Female	Male	Female	Male
F1	459.89 (23.49)	386.74 (20.38)	462.91 (25.85)	397.73 (23.41)
F2	1725.25 (118.38)	1395.27 (102.29)	1710.54 (120.02)	1426.28 (115.82)

Table 3.27 indicates that for female speakers, epenthetic /ɨ/ displayed a lower F1 and a higher F2 than lexical /ɨ/, whereas for male speakers, epenthetic /ɨ/ had a lower F1 and a lower F2 compared to lexical /ɨ/. To assess whether the mean F1 and F2 differences between epenthetic /ɨ/ and lexical /ɨ/ were statistically significant, a mixed-effects regression analysis was performed using the lmer() function. The best-fitting model for F1 and F2 formant values was selected through ANOVA comparisons and it matched the model used at the normal speech rate. The best model incorporated fixed effects for gender (female vs. male), place of articulation (alveolar vs. bilabial vs. velar), and origin (epenthetic vs. lexical), with subject and word included as random effects.

Table 3.28 Results for F1 and F2 of epenthetic /ɨ/ and lexical /ɨ/ at fast speech rate

F1	Estimate	Std. Error	t-value	Pr (>| t |)
(Intercept)	425.8025	15.6942	27.1312	<0.0001 ***
Gender Male	−50.3942	7.6024	−6.6287	<0.0001 ***
Place Alveolar	10.1396	14.5396	0.6974	0.4856
Place Bilabial	15.0911	12.0315	1.2543	0.2097
Origin Korean	1.5329	4.6021	0.3331	0.7392
F2	**Estimate**	**Std. Error**	**t-value**	**Pr (>| t |)**
(Intercept)	1432.4623	49.6229	28.8670	<0.0001 ***
Gender Male	−363.7855	26.6742	−13.6381	<0.0001 ***
Place Alveolar	34.3417	30.2114	1.1367	0.2556
Place Bilabial	−20.5241	59.7426	−0.3435	0.7312
Origin Korean	13.6098	41.3652	0.3290	0.7421

In Table 3.28, only gender influenced both F1 and F2, with male speakers showing lower F1 and F2 values than female speakers (F1: p <0.0001; F2: p <0.0001). There was no significant difference in F1 and F2 between epenthetic /ɨ/ and lexical /ɨ/ (F1: p = 0.7392; F2: p = 0.7421), and the place of articulation did not impact F2 at the fast speech rate (alveolar: p = 0.2556; bilabial: p = 0.7312). To examine whether place of articulation consistently lacked an effect on the F2 of both epenthetic /ɨ/ and lexical /ɨ/, additional statistical analysis was conducted.

Table 3.29 Tukey's pairwise comparisons of F2 across places of articulation at fast speech rate

Female	Place	Comparison	Estimate	Std. Error	t-value	Pr (>|t|)
	Alveolar	Epenthetic – Lexical	7.4531	5.5126	1.3521	0.1771
	Velar	Epenthetic – Lexical	–9.7128	7.0027	–1.3869	0.1655
	Bilabial	Epenthetic – Lexical	–2.5354	3.9678	–0.6390	0.5224
Male	**Place**	**Comparison**	**Estimate**	**Std. Error**	**t-value**	**Pr (>|t|)**
	Alveolar	Epenthetic – Lexical	–5.0214	4.1810	–1.2009	0.3078
	Velar	Epenthetic – Lexical	7.3487	6.2971	1.1672	0.2431
	Bilabial	Epenthetic – Lexical	–3.4925	4.7196	–0.7401	0.4569

As shown in Table 3.29, for female speakers, epenthetic /ɨ/ showed a higher F2 than lexical /ɨ/ following an alveolar consonant, but a lower F2 following velar and bilabial consonants. For male speakers, epenthetic /ɨ/ had a higher F2 than lexical /ɨ/ after a velar consonant, but a lower F2 after alveolar and bilabial consonants. However, these differences were not statistically significant for either females (alveolar: p = 0.1771; velar: p = 0.1655; bilabial: p = 0.5224) or males (alveolar: p = 0.3078; velar: p = 0.2431; bilabial: p = 0.4569) indicating that F2 does not significantly differ between epenthetic /ɨ/ and lexical /ɨ/ based on place of articulation at the fast speech rate.

Next, Table 3.30 presents the mean duration of epenthetic /ɨ/ and lexical /ɨ/, and Table 3.31 provides the statistical results for their durations. The best model for vowel durations based on the lmer() function had fixed effects for gender (female vs. male), origin (epenthetic vs. lexical), vowel position (final vs. non-final), and syllable structure (closed vs. open) and speech rate (fast vs. normal) with subject and word as random effects.

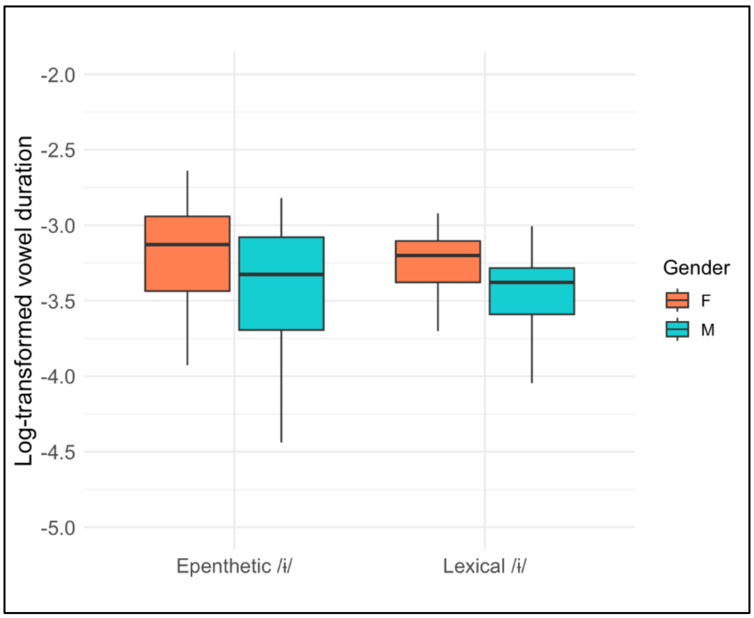

Figure 3.25 Vowel durations (log-transformed) of epenthetic /ɨ/ and lexical /ɨ/ for all speakers at fast speech rate

Table 3.30 Mean durations (s) with SD of epenthetic /ɨ/ and lexical /ɨ/ for all speakers at fast speech rate

Fast rate	Epenthetic /ɨ/		Lexical /ɨ/	
	Female	Male	Female	Male
	0.0431 (0.0133)	0.0352 (0.0128)	0.0420 (0.0127)	0.0343 (0.0115)

Table 3.31 Results of the mixed-effects model for durations of epenthetic /ɨ/ and lexical /ɨ/

	Estimate	Std. Error	t-value	Pr (>| t |)
(Intercept)	0.0573	0.0041	13.9756	<0.0001 ***
Gender Male	−0.0072	0.0032	−2.2499	0.0476 *
Origin Korean	0.0014	0.0011	1.2726	0.3276
Position Final	0.0071	0.0029	2.4483	0.0198 *
Structure Open	0.0016	0.0015	1.0667	0.3192
Rate Fast	−0.0315	0.0197	−1.5990	0.0058 **

Since the best mixed-effects model in Table 3.31 included speech rate as a fixed effect across both speech rates, Tukey's pairwise comparisons were conducted to get the results for the fast speech rate. The result showed that the durations of epenthetic /ɨ/ and lexical /ɨ/ at the fast speech rate did not show a significant difference (p = 0.9011). The statistical result is presented in detail in Table E6 in Appendix E.

To examine the effects of gender, vowel position, and syllable structure on epenthetic /ɨ/ and lexical /ɨ/ at the fast speech rate, Tukey's pairwise comparisons were conducted.

Table 3.32 Tukey's pairwise comparisons of durations by gender, vowel position, syllable structure at fast speech rate

Origin	Comparison (gender)	Estimate	Std. Error	t-value	Pr (>|t|)
Epenthetic /ɨ/	Female – Male	0.0079	0.0032	2.4688	0.0143 *
Lexical /ɨ/	Female – Male	0.0064	0.0031	2.0645	0.0375 *
Origin	Comparison (vowel position)	Estimate	Std. Error	t-value	Pr (>|t|)
Epenthetic /ɨ/	Non final – Final	−0.0013	0.0007	−1.8571	0.0712
Lexical /ɨ/	Non final – Final	0.0016	0.0009	1.7778	0.0699
Origin	Comparison (syllable structure)	Estimate	Std. Error	t-value	Pr (>|t|)
Epenthetic /ɨ/	Open – Closed	0.0012	0.0007	1.7143	0.0931
Lexical /ɨ/	Open – Closed	−0.0015	0.0010	−1.5000	0.1302

As Table 3.32 presents, both epenthetic /ɨ/ and lexical /ɨ/ were shorter when produced by male speakers (epenthetic /ɨ/: p = 0.0143; lexical /ɨ/: p = 0.0375). On the other hand, vowel position had no effect (epenthetic /ɨ/: p = 0.0712; lexical /ɨ/: p = 0.0699). Also, syllable structure did not influence durations (epenthetic /ɨ/: p = 0.0931; lexical /ɨ/: p = 0.1302).

In summary, the statistical analysis at the fast speech rate found that the F1 and F2 values of epenthetic /ɨ/ matched those of lexical /ɨ/ across various places of articulation for both genders. The duration of epenthetic /ɨ/ was also comparable to that of lexical /ɨ/ regardless of gender, vowel position, and syllable structure.

3.3.2.2.2. Epenthetic /i/ and lexical /i/ at the fast speech rate

A total of 3,287 vowels were collected from 30 speakers in fast speech.

Table 3.33 Number of analyzed epenthetic /i/ and lexical /i/ at fast speech rate

	Epenthetic /i/		Lexical /i/		
	Female	Male	Female	Male	
	764	877	756	890	
Total	1,641		1,646		3,287

In Table 3.33, this analysis included 1,641 epenthetic /ɨ/ and 1,646 lexical /ɨ/. Figures 3.16 and 3.17 illustrate the mean F1 and F2 values for 15 female and 15 male speakers, respectively, with each data point representing the mean F1 and F2 values per speaker.

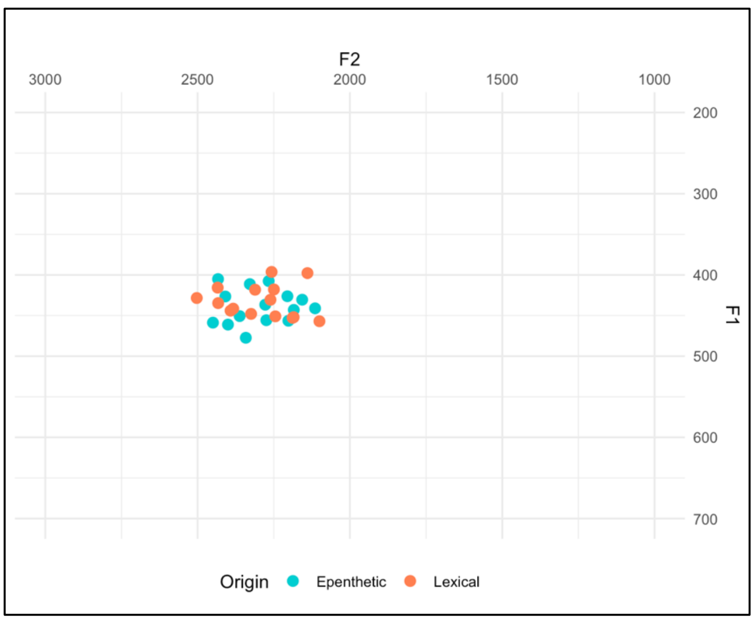

Figure 3.26 Mean F1 and F2 values (Hz) of epenthetic /i/ and lexical /i/ for 15 female speakers at fast speech rate

Figure 3.27 Mean F1 and F2 values (Hz) of epenthetic /i/ and lexical /i/ for 15 male speakers at fast speech rate

Table 3.34 Mean F1 and F2 values (Hz) with SD of epenthetic /i/ and lexical /i/ for all speakers at fast speech rate

	Epenthetic /i/		Lexical /i/	
	Female	Male	Female	Male
F1	435.87 (31.88)	369.01 (33.04)	427.25 (35.02)	373.52 (27.48)
F2	2309.25 (123.33)	1901.63 (104.92)	2292.32 (134.49)	1872.71 (121.05)

Table 3.34 show that (a) for female speakers, epenthetic /i/ had a higher F1 and a higher F2 compared to lexical /i/ and (b) for male speakers, epenthetic /i/ showed a lower F1 and a higher F2 than lexical /i/. To evaluate if the differences in mean F1 and F2 formant values between epenthetic /i/ and lexical /i/ were statistically significant, the mixed-effects model was performed by using the lmer() function. One best model for F1/F2 values and duration was chosen based on ANOVA comparisons and it was consistent with the model applied for epenthetic /i/ and lexical /i/ at the normal speech rate. The model included gender (female vs. male), origin (epenthetic vs. lexical), speech rate (fast vs. normal) as fixed effects, with subject and word as random effects.

Table 3.35 Results for F1 and F2 of epenthetic /i/ and lexical /i/

F1	Estimate	Std. Error	t-value	Pr (>| t |)
(Intercept)	378.6012	8.1051	46.7115	<0.0001 ***
Gender Male	−40.0083	10.3137	−3.8791	<0.0001 ***
Origin Korean	11.1726	17.6256	0.6339	0.5262
Rate Fast	47.6917	16.4609	2.8973	0.0038 *
F2	Estimate	Std. Error	t-value	Pr (>| t |)
(Intercept)	2182.6143	35.7192	61.1048	<0.0001 ***
Gender Male	−391.2632	46.8915	−8.3440	<0.0001 ***
Origin Korean	9.8967	33.3093	0.2971	0.7671
Rate Fast	−96.3413	29.7254	−3.2411	0.0012 **

As shown in Table 3.35, the best mixed-effects model had speech rate as a fixed effect, so this model reflects the influence of these variables in both normal and fast speech rates. Therefore, Tukey's pairwise comparisons were conducted exclusively at the fast speech rate to specifically investigate the effects of gender and origin.

Table 3.36 Tukey's pairwise comparisons of F1 and F2 of epenthetic /i/ and lexical /i/ by origin for female and male speakers at fast speech rate

Female	F1	Comparison (origin)	Estimate	Std. Error	t-value	Pr (>|t|)
		Epenthetic /i/ – Lexical /i/	8.6213	2.9783	2.8947	0.5661
	F2	Comparison (origin)	Estimate	Std. Error	t-value	Pr (>|t|)
		Epenthetic /i/ – Lexical /i/	16.9338	5.6103	3.0183	0.7359
Male	F1	Comparison (origin)	Estimate	Std. Error	t-value	Pr (>|t|)
		Epenthetic /i/ – Lexical /i/	−3.5827	1.4881	−2.4075	0.8152
	F2	Comparison (origin)	Estimate	Std. Error	t-value	Pr (>|t|)
		Epenthetic /i/ – Lexical /i/	9.2916	4.0783	2.2783	0.5638

In Table 3.36, the results showed that the F1 and F2 formant values for epenthetic /ɨ/ were the same as those of lexical /ɨ/ in female (F1: $p = 0.5661$; F2: $p = 0.7359$) and male (F1: $p = 0.8152$; F2: $p = 0.5638$) speakers.

Next, Table 3.37 is about the mean duration of epenthetic /ɨ/ and lexical /ɨ/, and Table 3.38 provides the statistical results for their durations.

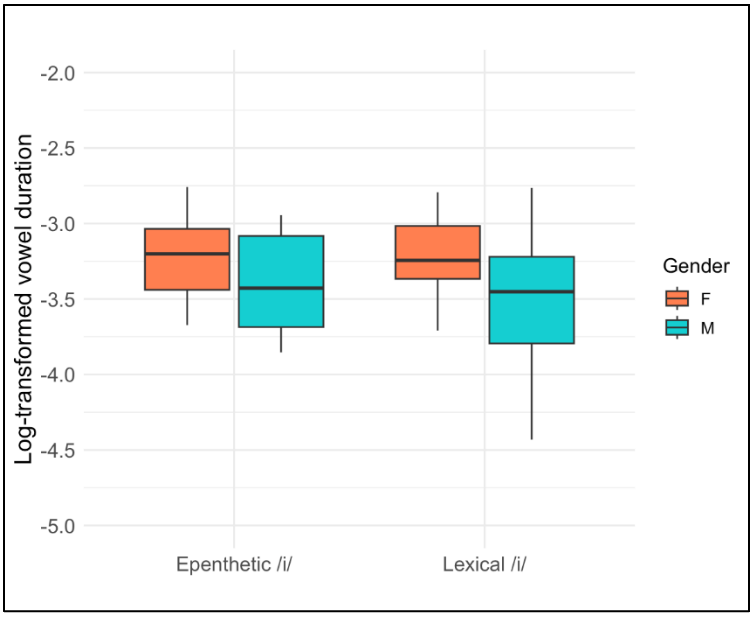

Figure 3.28 Vowel durations (log-transformed) of epenthetic /i/ and lexical /i/ for all speakers at fast speech rate

Table 3.37 Mean durations (s) with SD of epenthetic /i/ and lexical /i/ for all speakers at fast speech rate

Fast rate	Epenthetic /i/		Lexical /i/	
	Female	Male	Female	Male
	0.0422 (0.0117)	0.0347 (0.0111)	0.0425 (0.0106)	0.0339 (0.0129)

Table 3.38 Results for durations of epenthetic /i/ and lexical /i/

	Estimate	Std. Error	t-value	Pr (>| t |)
(Intercept)	0.0463	0.0157	2.9490	0.0020 **
Gender Male	−0.0079	0.0032	−2.4688	0.0372 *
Origin Korean	0.0051	0.0201	0.2537	0.8029
Rate Fast	−0.0174	0.0078	−2.2308	0.0021 **

Table 3.38 shows the overall effect of these variables across both normal and fast speech rates, so Tukey's pairwise comparisons were performed specifically for the fast speech rate. The result showed that the durations of epenthetic /i/ and lexical /i/ at the fast speech rate were not significantly different from each other (p = 0.0719). A detailed statistical result is provided in Table E7 in Appendix E. In addition, Tukey's pairwise comparisons showed that both epenthetic /i/ and lexical /i/ at the fast speech rate were longer when they were produced by female speakers (epenthetic /i/: p = 0.0357; lexical /i/: p = 0.0124). The

results of the statistical analysis are outlined in Table E8 in Appendix E.

In this section, the statistical analysis revealed that at the fast speech rate, the F1 and F2 values of epenthetic /i/ were similar to those of lexical /i/ in both genders, and male speakers demonstrated longer durations for both epenthetic /i/ and lexical /i/.

3.3.2.3 Overview of the shift from normal speech to fast speech

The shift from the normal speech rate to the fast speech rate caused the phonetic changes across genders. First, Figure 3.29 and Table 3.39 show the mean F1 and F2 values depending on the different speech rates for female speakers.

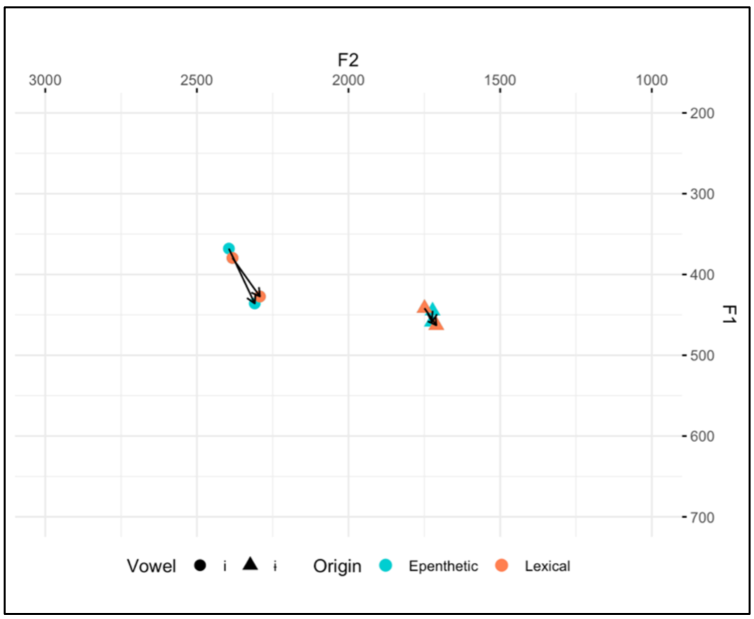

Figure 3.29 F1 and F2 shifts (Hz) in epenthetic and lexical vowels for female speakers, with arrows indicating the transition from normal to fast speech rates

Table 3.39 Overall mean F1 and F2 values (Hz) with SD of epenthetic and lexical vowels for female speakers at normal and fast speech rates

Female	Epenthetic /ɨ/		Lexical /ɨ/	
	Normal speech	Fast speech	Normal speech	Fast speech
F1	445.01 (35.05)	459.89 (23.49)	441.79 (33.59)	462.91 (25.85)
F2	1722.85 (124.82)	1725.25 (118.38)	1749.42 (118.14)	1710.54 (120.02)
	Epenthetic /i/		Lexical /i/	
	Normal speech	Fast speech	Normal speech	Fast speech
F1	368.01 (34.23)	435.87 (31.88)	379.59 (35.81)	427.25 (35.02)
F2	2394.43 (159.17)	2309.25 (123.33)	2382.64 (159.75)	2292.32 (134.49)

As Figure 3.29 and Table 3.39 show, epenthetic /i/ and lexical /i/ show greater F1 and F2 changes compared to epenthetic /ɨ/ and lexical /ɨ/ for female speakers.

Next, Figure 3.30 and Table 3.40 indicate the mean F1 and F2 values for male speakers across different speech rates.

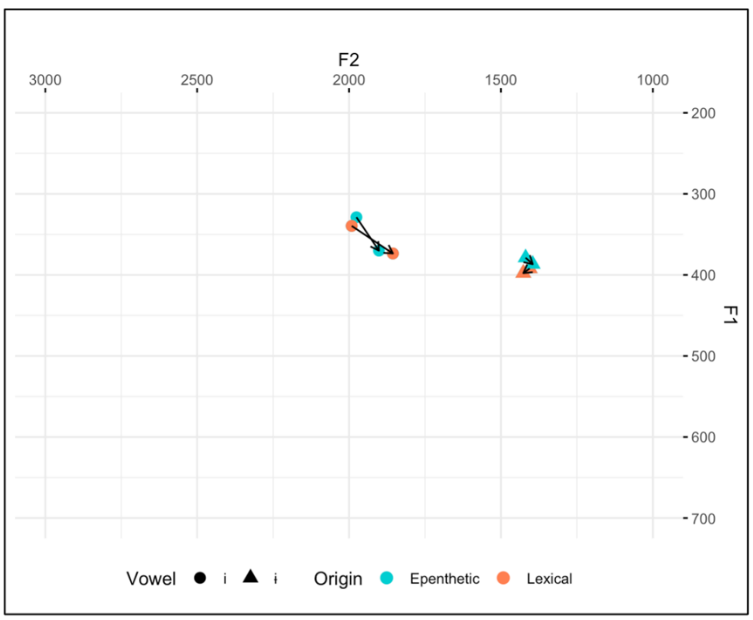

Figure 3.30 F1 and F2 shifts (Hz) in epenthetic and lexical vowels for male speakers, with arrows indicating the transition from normal to fast speech rates

Table 3.40 Overall mean F1 and F2 values (Hz) with SD of epenthetic and lexical vowels for male speakers at normal and fast speech rates

Male	Epenthetic /ɨ/		Lexical /ɨ/	
	Normal speech	Fast speech	Normal speech	Fast speech
F1	378.74 (30.98)	386.74 (20.38)	392.07 (30.28)	397.73 (23.41)
F2	1418.74 (115.63)	1395.27 (102.29)	1405.32 (116.35)	1426.28 (115.82)
	Epenthetic /i/		Lexical /i/	
	Normal speech	Fast speech	Normal speech	Fast speech
F1	328.76 (36.34)	369.01 (33.04)	339.51 (28.67)	373.52 (27.48)
F2	1975.82 (139.61)	1901.63 (104.92)	1991.38 (135.85)	1872.71 (121.05)

As illustrated in Figure 3.30 and Table 3.40, epenthetic /i/ and lexical /i/ exhibit larger F1 and F2 variations than epenthetic /ɨ/ and lexical /ɨ/ for male speakers, similar to female speakers.

Durational differences were also observed as a function of speech rate, as shown in Table 3.41.

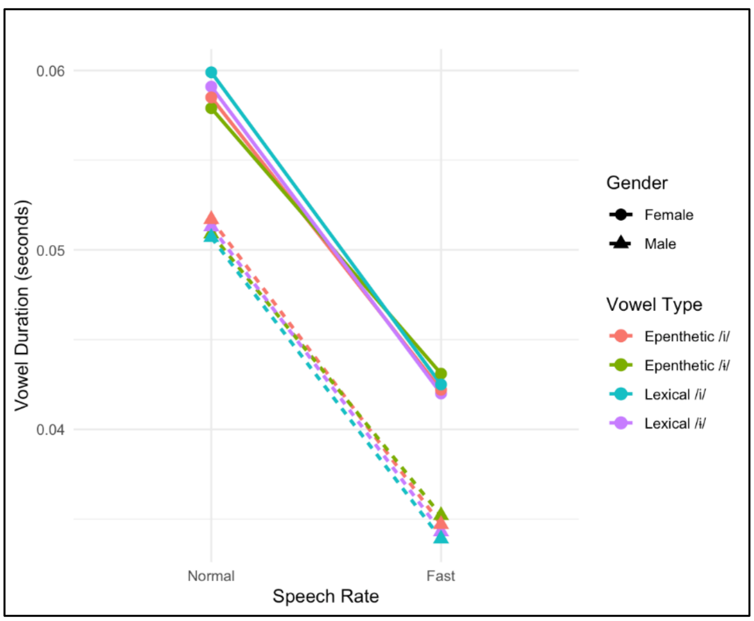

Figure 3.31 Vowel durational shifts (s) in epenthetic and lexical vowels for all speakers

Table 3.41 Overall mean durations (s) with SD of epenthetic and lexical vowels for all speakers

Normal rate	Epenthetic /ɨ/		Lexical /ɨ/	
	Female	Male	Female	Male
	0.0579 (0.0146)	0.0509 (0.0139)	0.0591 (0.0158)	0.0513 (0.0163)
Fast rate	Epenthetic /ɨ/		Lexical /ɨ/	
	Female	Male	Female	Male
	0.0431 (0.0133)	0.0352 (0.0128)	0.0420 (0.0127)	0.0343 (0.0115)
Normal rate	Epenthetic /i/		Lexical /i/	
	Female	Male	Female	Male
	0.0585 (0.0192)	0.0517 (0.0174)	0.0599 (0.0185)	0.0507 (0.0166)
Fast rate	Epenthetic /i/		Lexical /i/	
	Female	Male	Female	Male
	0.0422 (0.0117)	0.0347 (0.0111)	0.0425 (0.0106)	0.0339 (0.0129)

In Table 3.41, vowel durations become shorter at the fast speech rate regardless of origin (epenthetic vs. lexical), gender (female vs. male), vowel type (/ɨ/ vs. /i/).

In summary, the F1 and F2 formant values of epenthetic /i/ and lexical /i/ appear to vary depending on speech rate, while the F1 and F2 formant values of epenthetic /ɨ/ and lexical /ɨ/ show less variation. Specifically, speakers produced epenthetic /i/ and lexical /i/ with significantly higher F1 and lower F2 at the fast speech rate compared to the normal speech rate. This may be related to vowel centralization at the fast speech rate. Regarding vowel duration, vowels were produced more briefly at the fast speech rate than at the normal speech rate. In the next section, statistical analysis is conducted to support these observations.

3.3.2.3.1 Epenthetic /ɨ/ and lexical /ɨ/

The best mixed-effects model for the F1 and F2 formant values of epenthetic /ɨ/ and lexical /ɨ/ did not include speech rate, either at normal or fast speech rates in §3.3.2.1.1 and §3.3.2.2.1. However, to investigate the effect of speech rate, it was included as a fixed effect as shown in Table 3.42.

Table 3.42 Results for F1 and F2 of epenthetic /ɨ/ and lexical /ɨ/

F1	Estimate	Std. Error	t-value	Pr (>| t |)
(Intercept)	450.1804	4.5945	97.9825	<0.0001 ***
Gender Male	−55.6561	5.0649	−10.9886	0.0112 *
Place Alveolar	19.0419	6.0117	3.1675	0.3537
Place Bilabial	−10.2936	7.0212	−1.4661	0.4549
Origin Korean	4.5232	4.0703	1.1113	0.2661
Rate Fast	7.3828	3.4795	2.1218	0.0702
F2	**Estimate**	**Std. Error**	**t-value**	**Pr (>| t |)**
(Intercept)	1715.0857	22.9238	74.8168	<0.0001 ***
Gender Male	−312.0502	26.4776	−11.7854	0.0141 *
Place Alveolar	293.5315	59.2924	4.9506	0.0312 *
Place Bilabial	−51.3314	17.8697	−2.8725	0.0497 *
Origin Korean	12.1769	18.7062	0.6510	0.5159
Rate Fast	−11.4873	15.5399	−0.7392	0.5372

Table 3.42 presents similar results regarding gender, place of articulation, and origin when compared to the best model. Interestingly, speech rate had no effect on the F1 and F2 of epenthetic /ɨ/ and lexical /ɨ/ (F1: $p = 0.0702$; F2: $p = 0.5372$). Tukey's pairwise comparisons were conducted to determine whether this tendency applied to both epenthetic /ɨ/ and lexical /ɨ/.

Table 3.43 Tukey's pairwise comparisons of F1 and F2 of epenthetic /ɨ/ and lexical /ɨ/ by speech rate for female and male speakers

Female	F1		Comparison	Estimate	Std. Error	t-value	Pr (>|t|)
		Epenthetic /ɨ/	Fast – Normal	14.5349	20.2438	0.7179	0.4726
		Lexical /ɨ/	Fast – Normal	19.1472	20.4345	0.9371	0.3488
	F2		Comparison	Estimate	Std. Error	t-value	Pr (>|t|)
		Epenthetic /ɨ/	Fast – Normal	3.3052	15.8143	0.2093	0.8342
		Lexical /ɨ/	Fast – Normal	–37.9455	42.3972	–0.8956	0.3706
Male	F1		Comparison	Estimate	Std. Error	t-value	Pr (>|t|)
		Epenthetic /ɨ/	Fast – Normal	9.4918	15.4087	0.6161	0.5378
		Lexical /ɨ/	Fast – Normal	5.9684	13.5337	0.4415	0.6591
	F2		Comparison	Estimate	Std. Error	t-value	Pr (>|t|)
		Epenthetic /ɨ/	Fast – Normal	–19.6426	39.6020	–0.4969	0.1905
		Lexical /ɨ/	Fast – Normal	21.4031	46.4275	0.4618	0.3924

In Tables 3.43, speech rate did not affect the F1 and F2 values of both epenthetic /ɨ/ and lexical /ɨ/.

Next, epenthetic /ɨ/ and lexical /ɨ/ were pronounced with a short duration at the fast speech rate in both genders. The best mixed-effects model already included speech rate as a fixed effect, so the same results in §3.3.2.1.1 and §3.3.2.2.1 are discussed here, again.

Table 3.44 Results for durations of epenthetic /ɨ/ and lexical /ɨ/

	Estimate	Std. Error	t-value	Pr (>| t |)
(Intercept)	0.0573	0.0041	13.9756	<0.0001 ***
Gender Male	−0.0072	0.0032	−2.2499	0.0476 *
Origin Korean	0.0014	0.0011	1.2726	0.3276
Position Final	0.0071	0.0029	2.4483	0.0198 *
Structure Open	0.0016	0.0015	1.0667	0.3192
Rate Fast	−0.0315	0.0197	−1.5990	0.0058 **

As Table 3.44 presents, the vowels as the fast speech rate were produced with a short duration (p = 0.0058).

3.3.2.3.2 Epenthetic /i/ and lexical /i/

As the best mixed-effects model already incorporated speech rate as a fixed effect, the findings from §3.3.2.1.2 and §3.3.2.2.2 are reexamined here in Table 3.26.

Table 3.45 Results for F1 and F2 of epenthetic /i/ and lexical /i/

F1	Estimate	Std. Error	t-value	Pr (>| t |)
(Intercept)	378.6012	8.1051	46.7115	<0.0001 ***
Gender Male	−40.0083	10.3137	−3.8791	<0.0001 ***
Origin Korean	11.1726	17.6256	0.6339	0.5262
Rate Fast	47.6917	16.4609	2.8973	0.0038 *
F2	**Estimate**	**Std. Error**	**t-value**	**Pr (>| t |)**
(Intercept)	2182.6143	35.7192	61.1048	<0.0001 ***
Gender Male	−391.2632	46.8915	−8.3440	<0.0001 ***
Origin Korean	9.8967	33.3093	0.2971	0.7671
Rate Fast	−96.3413	29.7254	−3.2411	0.0012 **

As shown in Table 3.45, speech rate is significant for F1 (p = 0.0038) and F2 (p = 0.0012), and Tukey's pairwise comparisons were performed to assess whether this pattern was present in both epenthetic /i/ and lexical /i/.

Table 3.46 Tukey's pairwise comparisons of F1 and F2 of epenthetic /i/ and lexical /i/ by speech rate for female and male speakers

Female	F1		Comparison	Estimate	Std. Error	t-value	Pr (>|t|)
		Epenthetic /i/	Fast – Normal	70.5233	22.3464	3.1559	0.0043 **
		Lexical /i/	Fast – Normal	51.3840	21.2682	2.4162	0.0156 *
	F2		Comparison	Estimate	Std. Error	t-value	Pr (>|t|)
		Epenthetic /i/	Fast – Normal	−89.5918	32.9623	−2.7181	0.0067 **
		Lexical /i/	Fast – Normal	−92.4056	36.1807	−2.5544	0.0106 *
Male	F1		Comparison	Estimate	Std. Error	t-value	Pr (>|t|)
		Epenthetic /i/	Fast – Normal	44.9682	14.4825	3.1058	0.0018 **
		Lexical /i/	Fast – Normal	35.3475	15.7871	2.2396	0.0251 *
	F2		Comparison	Estimate	Std. Error	t-value	Pr (>|t|)
		Epenthetic /i/	Fast – Normal	−61.2155	24.0154	−2.5499	0.0108 *
		Lexical /i/	Fast – Normal	−56.3893	20.2257	−2.7884	0.0053 **

Table 3.46 shows that speech rate had a significant effect on the F1 and F2 formant values of epenthetic /i/ and lexical /i/ for both genders. Specifically, F1 increased, and F2 decreased for both epenthetic and lexical /i/ across genders. This indicates that vowel centralization occurred at the fast speech rate for both epenthetic and lexical /i/.

For vowel duration, both epenthetic and lexical /i/ were produced with shorter durations at the fast speech rate across genders. Since the best mixed-effects model already included speech rate as a fixed effect, the same findings from §3.3.2.1.2 and §3.3.2.2.2 are revisited here.

Table 3.47 Results for durations of epenthetic /i/ and lexical /i/

	Estimate	Std. Error	t-value	Pr (>| t |)
(Intercept)	0.0463	0.0157	2.9490	0.0020 **
Gender Male	−0.0079	0.0032	−2.4688	0.0372 *
Origin Korean	0.0051	0.0201	0.2537	0.8029
Rate Fast	−0.0174	0.0078	−2.2308	0.0021 **

Table 3.47 shows that vowel durations at the fast speech rate were shorter than those at the normal speech rate (p = 0.0021).

3.4 Conclusions

Chapter 3 investigated the phonetic differences between epenthetic and lexical vowels in Korean in passage-level read speech and across different speech rates. By analyzing formant values and vowel durations, the study aimed to determine whether epenthetic vowels exhibit different or similar phonetic characteristics compared to lexical vowels.

In passage-level read speech, epenthetic /ɨ/ and lexical /ɨ/ produced by Korean monolinguals were analyzed, and the results indicated that they had similar formant values and durations. This finding contrasts with my previous study (2022) which found that epenthetic /ɨ/ had a higher F2 than lexical /ɨ/.

Next, epenthetic and lexical vowels were found to be phonetically similar across different speech rates and exhibited similar patterns. Specifically, at the normal speech rate, the F2 formant values of epenthetic /ɨ/ and lexical /ɨ/ varied depending on the place of articulation of the preceding consonant, while their F1 formant values remained stable. Furthermore, both epenthetic and lexical /ɨ/ had longer durations when produced by male speakers, when they occurred in the final syllable of a word, and when the syllable was open. Similarly, at the normal speech rate, epenthetic /i/ and lexical /i/ exhibited the same formant values and were produced with a shorter duration by male speakers.

At the fast speech rate, the F2 formant variations based on the place of articulation of the preceding consonant disappeared for both epenthetic and lexical /ɨ/. The durational differences associated with final syllable position and open syllable structure also disappeared in both cases. However, male speakers continued to produce epenthetic /ɨ/ and lexical /ɨ/ with a longer duration than female speakers at the fast speech rate. Similarly, epenthetic /i/ and lexical /i/ exhibited similar formant values, and male speakers produced them with a shorter duration than female speakers at the given speech rate. Lastly, epenthetic /ɨ/ and lexical /ɨ/ demonstrated less centralizaation with increasing speech rate compared to epenthetic /i/ and lexical /i/. These findings will be further discussed in Chapter 5.

CHAPTER 4

PERCEPTION OF VOWEL EPENTHESIS

4.1 Introduction

This chapter focuses on identifying the linguistic factors influencing native Korean listeners' perception of /ɨ/ and /i/ epenthesis. For /ɨ/ epenthesis, the voicing, release, and place of articulation of the final consonant and the tenseness of the pre-final vowel are examined. Furthermore, the study investigates whether native Korean listeners who are better at discriminating between English tense and lax vowels perceive /ɨ/ epenthesis more frequently in contexts with a pre-final tense vowel. In the case of /i/ epenthesis, this study examines the voicing and noise duration of the final consonant, as well as the tenseness of the pre-final vowel. Since /i/ epenthesis occurs only after English post-alveolar consonants, the place of articulation of the final consonant is not taken into consideration.

According to the regulations on loanword orthography (Ministry of Education 2017), /i/ epenthesis must occur after an English post-alveolar /ʃ/ which is realized as [s] in Korean at the end of words such as *fish* [p^hisi] and *cash* [k^hæsi]. However, Hwang (2006) argues that many English words ending in /ʃ/ are used on signs and in business names with epenthetic [y] as in *Fresh* [p^hɨlɛsy] and *Lush* [lʌsy]. This phenomenon may be caused by the perceptual similarity to the original English words. In Korean, [y] can also be considered as a diphthong since it sounds like [wi] (Ministry of Culture, Sports and Tourism 2017), so Korean [sy] sounds more similar to English /ʃ/. For example, Kang et al. (2000) argue that English /ʃ/ at the end of a word can be perceived either [si] or [sy] in English loanwords. It means that some native Korean listeners are familiar with [y] after English /ʃ/ and may perceive /i/ epenthesis in this context as perceptually unnatural. Thus, in this dissertation, the /i/ epenthesis stimuli did not include English nonce words ending in /ʃ/ even though /i/ epenthesis is grammatically required after

/ʃ/. Additionally, since this study examines voicing contrast, English words ending in /ʒ/, the voiced counterpart of /ʃ/, were also excluded from the /i/ epenthesis stimuli. Thus, while /i/ epenthesis occurs after English post-alveolar consonants /ʒ/, /ʃ/, /ʤ/, or /ʧ/, this study focuses on /i/ epenthesis following the affricates /ʤ/ and /ʧ/.

By analyzing both /ɨ/ and /i/ epenthesis under similar conditions, this study aims to identify parallels and differences in their perceptual patterns, providing deeper insight into how phonetic factors influence native Korean listeners' perception during the loanword adaptation process.

4.2 Overview of methodology

This study is designed to investigate how each individual factor—the release, voicing, and place of articulation of the final consonant, and the tenseness of the pre-final vowel—and their interactions affect native Korean listeners' perception of vowel epenthesis. A total of 30 native Korean listeners participated in the perceptual experiments. These participants formed a new pool of subjects, distinct from those involved in the previous production experiments.

The participants first took two discrimination tests (as outlined in detail in §4.2.2) followed by ABX tests. Two discrimination tests were designed to assess the ability to recognize and distinguish individual words including English tense or lax vowels (e.g., *peak* vs. *pick*). In the first test, participants are asked to identify the correct English words based on the audio. After completing the first test, participants had an optional five-minute break. Following the break, participants proceeded to the second discrimination test. The second test examined whether the two words heard from the audio are the same or different. Upon completing the second test, participants were allowed a 10-minute break before moving on to the ABX perceptual experiment (as described in detail in §4.2.3).

Generally, an ABX task assesses listeners' ability to discriminate between two initial stimuli A and B by comparing them with a third stimulus X. In this experiment, participants hear stimuli in the sequence A, B, and X and then decide whether X is more similar to A or B. In the present study, X is an

English nonce word, and A and B are the corresponding Korean forms with or without epenthetic vowels. The Gorilla Experiment Builder software was used to create and conduct the discrimination tests and ABX perceptual experiments.

A total of 30 participants took part in the discrimination tests and the ABX perceptual experiments conducted in various locations. Twenty-two participants took part in these experiments in quiet locations in Seoul, Korea, such as library study rooms and seminar rooms. The remaining eight participants completed the perceptual experiments in an attenuated sound booth located in the Linguistics Lab at the University of Georgia, USA.

4.2.1 Participants

A total of 30 native Korean listeners participated in two discrimination tests and ABX perceptual experiments. These participants were different individuals from those who took part in the previous production experiments. All participants were born and raised in Seoul, Korea ensuring that there were no dialectal variations that could influence the outcomes of the experiments. Of the 30 participants, 20 resided in Seoul, Korea, and had never lived in an English-speaking country. The remaining 10 participants had lived in Georgia, USA, for less than a year. Despite their stay in the USA, they continued to use Seoul Korean daily, whether at school, work, or in social settings based on the English Proficiency Self-Rating Questionnaire in Appendix A.

Table 4.1 Dataset of participant information

Participant Number	Age	Months in English-speaking Country	English Proficiency	Recording Location
F1	27	0	Group B	Seoul, Korea
F2	28	0	Group A	Seoul, Korea
F3	28	0	Group C	Seoul, Korea
F4	30	0	Group A	Seoul, Korea
F5	30	0	Group B	Seoul, Korea
F6	32	0	Group D	Seoul, Korea
F7	32	0	Group A	Seoul, Korea
F8	34	0	Group D	Seoul, Korea
F9	35	0	Group D	Seoul, Korea
F10	36	0	Group B	Seoul, Korea
F11	31	2	Group C	UGA
F12	32	2	Group C	UGA
F13	29	3	Group D	UGA
F14	32	3	Group B	UGA
F15	30	7	Group D	UGA
M16	29	0	Group C	Seoul, Korea
M17	29	0	Group B	Seoul, Korea
M18	30	0	Group D	Seoul, Korea
M19	30	0	Group B	Seoul, Korea
M20	30	0	Group A	Seoul, Korea
M21	30	0	Group B	Seoul, Korea
M22	30	0	Group C	Seoul, Korea
M23	30	0	Group D	Seoul, Korea
M24	31	0	Group B	Seoul, Korea
M25	32	0	Group C	Seoul, Korea
M26	30	2	Group C	UGA
M27	35	6	Group A	UGA
M28	34	8	Group A	UGA
M29	34	9	Group A	UGA
M30	37	9	Group C	UGA

Table 4.1 includes participant' numbers, ages, genders (F = female; M = male), the number of months the participant had spent in an English-speaking country, English proficiency level, and recording location. The average age of the participants was 31.23 years, and the average number of months living in an English-speaking country was 1.76 months. The participants' English proficiency level was based on English Proficiency Self-Rating Questionnaire, as described in Appendix A. This questionnaire was adapted from Park and Ziegler (2014), which adheres to the standards of the Common European

Framework of Reference for Languages (CEFR). Participants self-assessed their current English proficiency in reading, listening, speaking, and writing using five-point scales (1 to 5). The combined scores from these four areas were used to estimate their overall English proficiency. These scores were then categorized into four groups according to CEFR: (a) Group A: 17 to 20 (seven participants in this study), (b) Group B: 13 to 17 (eight participants), (c) Group C: 9 to 12 (eight participants), and (d) Group D: 4 to 8 (seven participants).

The questionnaire was necessary to recruit participants with varying levels of English proficiency. After measuring participants' self-assessed English proficiency via Google Forms, the English lax and tense vowel discrimination tests and the ABX perceptual experiments were conducted with participants.

4.2.2 English lax and tense vowel discrimination tests

One of the hypotheses in this study is that native Korean listeners with a better ability to distinguish between English tense and lax vowels show higher perceived epenthesis rates in English CVC monosyllabic words with a pre-final tense vowel. To evaluate participants' ability to distinguish between English tense and lax vowels, two different discrimination tests were designed and created using the Gorilla Experiment Builder. Before testing the main group of participants, a preliminary validation phase was conducted. In this step, one male and one female native English listener completed both discrimination tests. Any issues identified in this step were corrected to ensure the accuracy and reliability of the tests.

During the actual discrimination tests, participants viewed a computer screen similar to the one shown in Figure 4.1 below. On this screen, two-word options were displayed. After hearing an audio file played by the computer, participants selected the word they believed matched the audio.

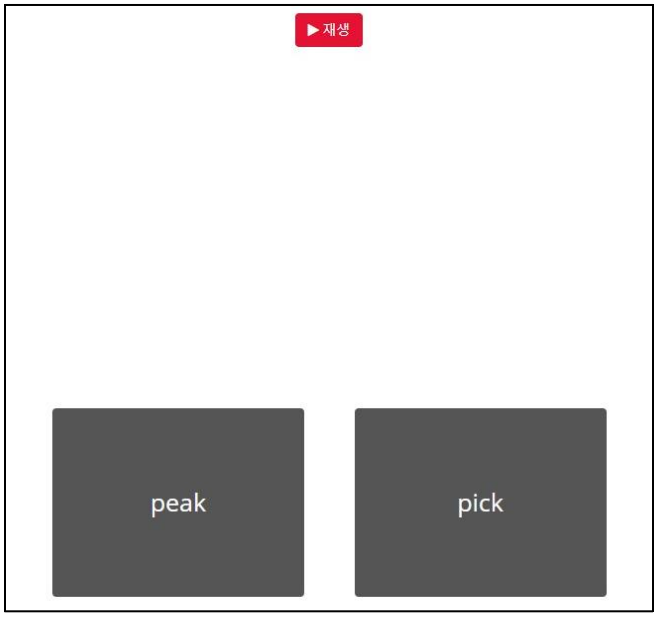

Figure 4.1 Sample of the first discrimination test

The first discrimination test included three trial word pairs, nine dummy word pairs, and thirty actual test word pairs, detailed in Appendix F. All stimuli were English words recorded by both female and male native English speakers. Each test word pair featured one word recorded by a female speaker and the other by a male speaker, with the gender order randomized to prevent bias.

Participants were provided with detailed instructions in Korean on the computer screen to ensure they fully understood the procedure. They were then instructed to begin the three trial pairs by clicking ‘Continue’ in Korean. During the trial phase, after clicking ‘Play’ in Korean, an audio file was played with a one-second delay. Participants could replay the audio by clicking ‘Play’ again, but only up to three times. Once they selected a word, the next trial started automatically.

The same procedure as in the trials was applied to the actual test. The actual test included three minimal pairs for the vowel contrast /u, ʊ/, twelve minimal pairs for /i, ɪ/, and nine dummy pairs, all presented in a random order to avoid any pattern recognition. The test design included repetition; fifteen minimal pairs were repeated twice, resulting in a total of thirty minimal pairs being tested. An optional five-minute break was included halfway through the test. After completing the first discrimination test, all participants were required to take a five-minute break before proceeding to the second test.

In the second discrimination test, participants were asked to determine whether two words they heard from the computer were the same or different. The second discrimination test consisted of three trial nonce word pairs, eight dummy nonce word pairs, and thirty-six actual test nonce word pairs (fourteen pairs for /i, ɪ/ and twenty-two pairs for /u, ʊ/), all detailed in Appendix F. All stimuli were recorded by male and female native English speakers. Each nonce word pair included one recording by a female speaker and one by a male speaker, with the gender order randomly determined to avoid bias.

Participants began the second discrimination test by reading detailed instructions in Korean on the computer screen, and they initiated the three trial pairs by clicking on 'Continue' in Korean. During each trial, two audio files were played consecutively with a one-second gap between them.
To help participants visually recognize the currently playing sound, the symbols '1' and '2' in blue circles blinked on the computer screen as each corresponding word was played, as illustrated in Figures 4.2 and 4.3.

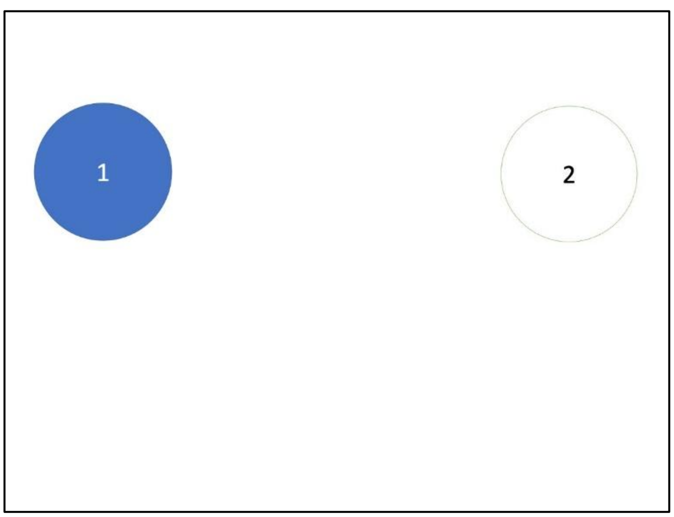

Figure 4.2 Sample of the first sound

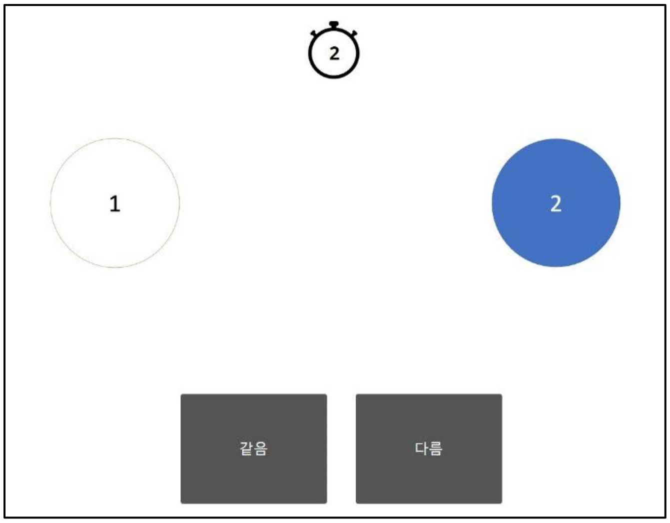

Figure 4.3 Sample of the second sound

Participants determined whether the two sounds they heard were the same or different. They indicated their choice by clicking 'Same' or 'Different' in Korean within a two-second window. Participants were allowed to listen to the audio files only once. If participants did not make a choice within the two seconds, the test automatically moved on to the next pair. The same procedural steps used in the trials were applied to the actual test. In the actual test, a total of twenty-two minimal pairs for the vowel contrast /u, ʊ/, fourteen minimal pairs for /i, ɪ/, and eight dummy pairs were used. These pairs were presented in a random order to prevent participants from anticipating the answers.

Participants had the option to take a five-minute break after completing half of the second discrimination test. After finishing the test, all participants were required to take a ten-minute break before proceeding to the ABX perceptual experiments.

4.2.3 ABX perceptual experiments

Generally, in ABX perceptual experiments, participants listen to stimuli A, B, and X consecutively and choose between A or B based on X. In this study, the ABX formats were generated using Gorilla Experiment Builder, and participants took part in this ABX perceptual experiment through this software as well.

Two ABX perceptual experiments were conducted in this study: the first on /ɨ/ epenthesis and the second on /i/ epenthesis. In the first ABX experiment, the X stimuli were English nonce words and were controlled based on the following factors. First**,** word length is a factor affecting /ɨ/ epenthesis. English monosyllabic words are more prone to /ɨ/ epenthesis compared to disyllabic words. Therefore, all English X stimuli were designed as monosyllabic CVC nonce words. Also, the occurrence of /ɨ/ epenthesis is also determined by the manner and place of articulation of the final stop. Specifically, /ɨ/ epenthesis consistently occurs following a fricative, whereas it does not occur after a sonorant. With a final stop, /ɨ/ epenthesis can either occur or not. Thus, in the stimuli, all final consonants were stops. Additionally, /ɨ/ epenthesis is more likely to occur when the final stop is coronal or dorsal compared to when it is labial. Thus, the final stops in the stimuli were classified as alveolar, bilabial, and velar to investigate their effects. The voicing of the final stop also plays a significant role in /ɨ/ epenthesis. When the final stop is voiced, the likelihood of /ɨ/ epenthesis increases. Therefore, the final stops in the stimuli were controlled to be either voiced or voiceless to assess the impact of voicing on the perception of vowel epenthesis. Next, the release of a final stop influences the occurrence of /ɨ/ epenthesis. If the final stop is released, there is a higher probability of /ɨ/ epenthesis. Accordingly, the final stops in the stimuli were categorized as either released or unreleased to examine the effect of this factor as shown in Figures 4.4 and 4.5.

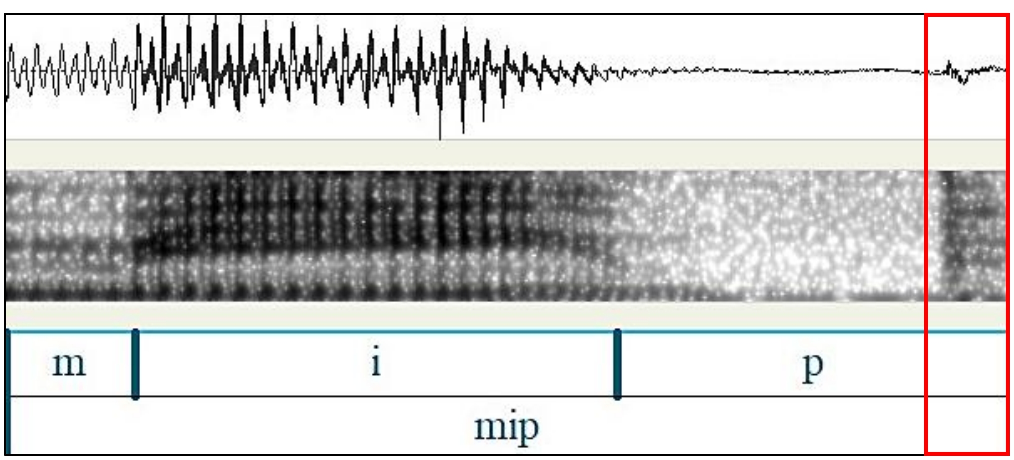

Figure 4.4 Spectrogram of [mip]

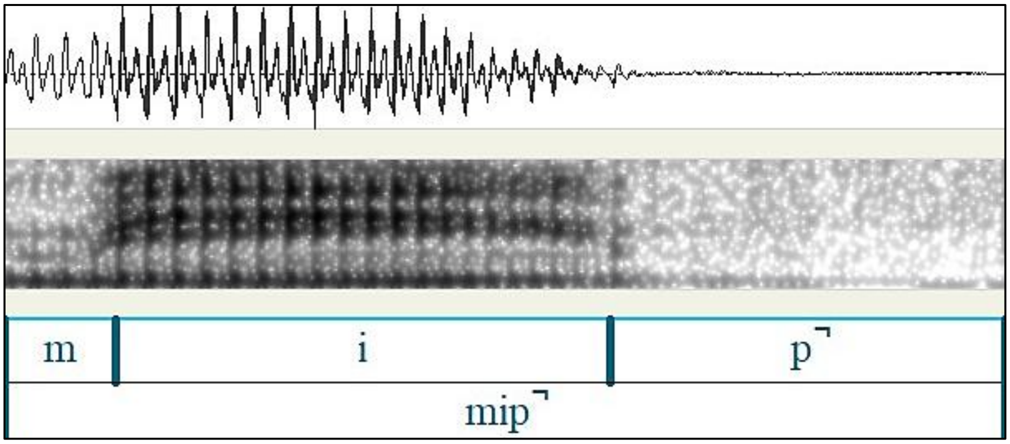

Figure 4.5 Spectrogram of [mip˺]

Figure 4.4 shows the release burst in the red box, but Figure 4.5 does not show it.

Lastly, the likelihood of /ɨ/ epenthesis is influenced by whether a pre-final vowel is tense or lax. Tense vowels tend to promote /ɨ/ epenthesis more frequently than lax vowels. Therefore, the vowels in the stimuli were controlled to be either tense or lax to examine their specific effects.

In the case of /i/ epenthesis, the voicing of the final consonant and the tenseness of the pre-final vowel were controlled in the same manner as in the experiment on /ɨ/ epenthesis. However, the final consonants /dʒ/ and /tʃ/ cannot be produced without release. Therefore, this study distinguishes between short and long consonants (e.g., [t͡ʃ] and [tʃː]) instead of using released and unreleased conditions. Particularly, the noise duration is measured, as shown in Figures 4.6 and 4.7.

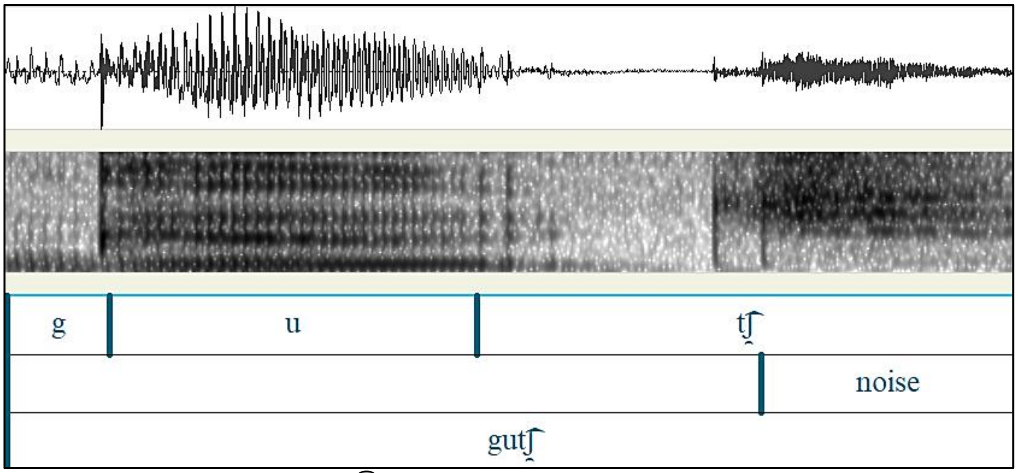

Figure 4.6 Spectrogram of [gut͡ʃ̮]

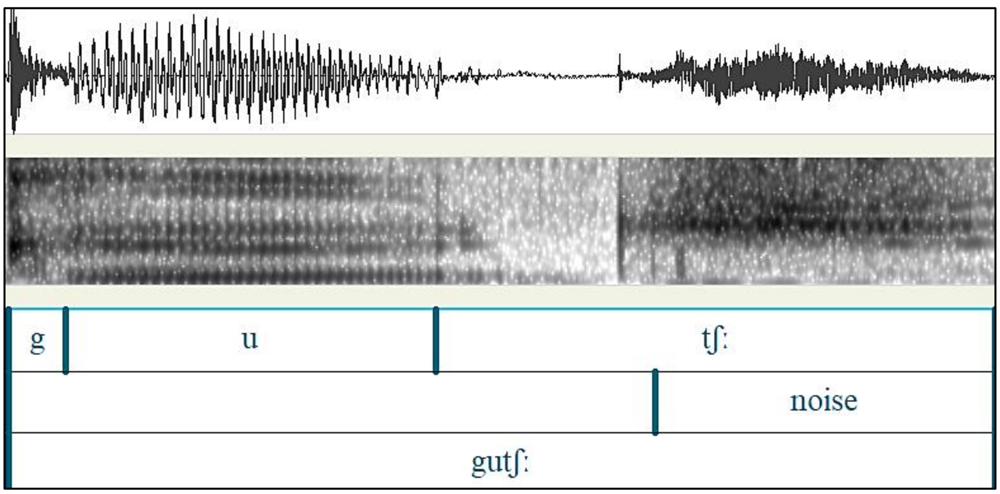

Figure 4.7 Spectrogram of [gutʃː]

As shown in Figures 4.6 and 4.7, [tʃː] has a longer noise duration than [t͡ʃ̮].

In ABX perceptual experiments, A and B were the corresponding Korean forms with or without vowel epenthesis. First, Table 4.2 provides examples of the ABX stimuli used for /ɨ/ epenthesis.

Table 4.2 Sample dataset of ABX sequences for /ɨ/ epenthesis

Korean A and B		English X
Without epenthesis	With epenthesis	
[tit]	[titʰɨ]	[dɪt]
[tit]	[titʰɨ]	[dɪt˺]
[tit]	[titɨ]	[dɪb]
[tit]	[titɨ]	[dɪb˺]
[tik]	[tikʰɨ]	[dik]
[tik]	[tikʰɨ]	[dik˺]
[tip]	[tipɨ]	[dib]
[tip]	[tipɨ]	[dib˺]

196 ABX target sequences and 36 ABX filler sequences were used in the perceptual experiment for epenthetic /ɨ/. ABX Stimuli in the perceptual experiment are listed in Appendix G. Each ABX target sequence was randomly presented to participants two times. 392 ABX sequences were collected from each participant excluding the filler sequences. As a result, a total of 11,760 ABX sequences (196 ABX sequences * 2 times * 30 participants) were collected in the perceptual experiment on /ɨ/ epenthesis.

Next, in the ABX perceptual experiment for /i/ epenthesis, 64 ABX target sequences and 16 ABX filler sequences were used, as shown in Table 4.3 (See Appendix H for a complete list of ABX stimuli). Each ABX target sequence was presented twice to participants in a random order, so 128 ABX sequences were collected from each participant excluding the filler sequences. Thus, a total of 3,840 ABX sequences (64 ABX sequences * 2 times * 30 participants) were collected in this experiment.

Table 4.3 Sample dataset of ABX sequences for /i/ epenthesis

Korean A and B		English X
Without epenthesis	With epenthesis	
[tit]	[titʃi]	[didʒː]
[tit]	[titʃi]	[did͡ʒ]
[tit]	[titʃʰi]	[ditʃː]
[tit]	[titʃʰi]	[dit͡ʃ]
[tit]	[titʃi]	[dɪdʒː]
[tit]	[titʃi]	[dɪd͡ʒ]
[tit]	[titʃʰi]	[dɪtʃː]
[tit]	[titʃʰi]	[dɪt͡ʃ]

(Note that English /tʃ/ and /dʒ/ are pronounced as Korean [t] in the Korean coda.)

In the ABX perceptual experiments, participants were asked to decide whether the English nonce word X sounded more similar to the first Korean nonce word A or the second Korean nonce word B after listening to all three stimuli in sequence. All English X stimuli were recorded by one male native English speaker and Korean A and B stimuli were recorded by two different female native Korean speakers using standard Korean. Each ABX sequence was constructed with Korean A and B stimuli produced by two different female native Korean speakers and the English X stimulus produced by one male native English speaker. The order of the two native Korean speakers was randomized in each sequence, but it was always followed by the native English speaker.

Participants were provided with detailed instructions for the ABX perceptual experiments in Korean on the computer screen and they began the trials for the first experiment on /ɨ/ epenthesis by clicking 'Continue' in Korean. During each trial, the three audio recordings were played consecutively and automatically with a 0.5-second interval between them. To help participants visually identify the sounds being played, the computer screen displayed the symbols '1', '2', and '3' in blue circles, corresponding to stimuli A, B, and X, respectively, as shown in Figures 4.8, 4.9, and 4.10.

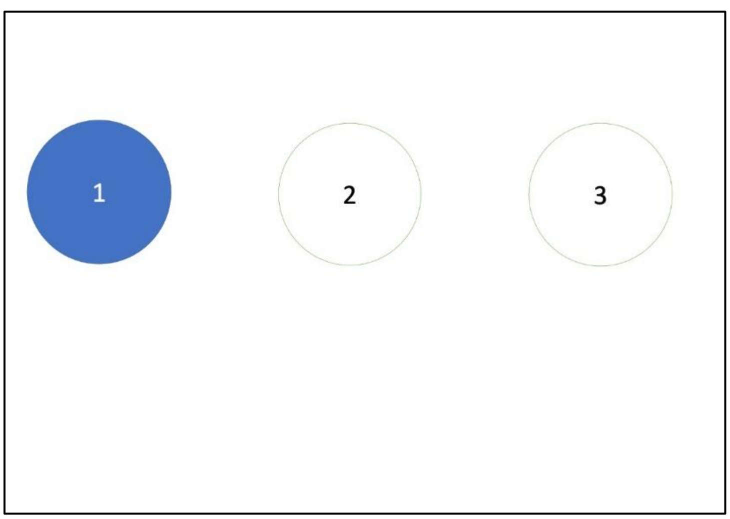

Figure 4.8 Sample for the first Korean sound A

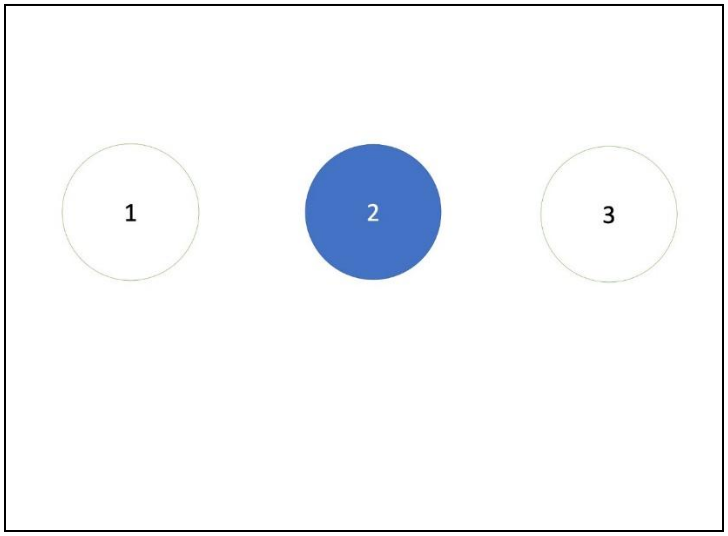

Figure 4.9 Sample for the second Korean sound B

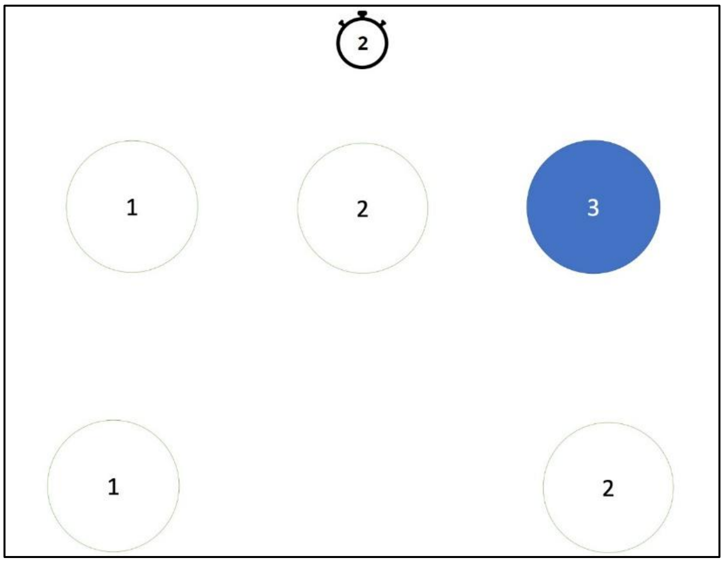

Figure 4.10 Sample for the English sound X

If participants thought the first Korean A sounded more like the third English X, they pressed ‘Z’ on the computer keyboard. If they thought the second Korean B sounded more like the third one, they pressed ‘M’ on the keyboard. Participants heard each ABX sequence only once. After two seconds of playback of English X, a blank screen appeared even if they did not make any choice, and one second later, a new ABX sequence was played. The same procedure used in the trials was applied to the actual experiment and participants were given the option to pause the perceptual experiment after completing half of it. The ABX experiment for /ɨ/ epenthesis was conducted first, followed by the experiment for /i/ epenthesis, which used the same procedure as the /ɨ/ epenthesis experiment.

4.2.4 Data extraction

The Gorilla Experiment Builder was used to conduct the experiments, and it automatically compiled the results within its database. For data extraction, all raw data was exported from the Gorilla Experiment Builder database into Excel. Once the data was imported into Excel, it was modified to accurately calculate and derive the test scores shown in Table 4.4.

Table 4.4 Sample dataset of test scores

Participant	Discrimination Test	Correct answer	Participant's answer	Score
1	1	peach	peach	1
1	1	heat	heat	1
1	1	sick	sick	1
1	1	tin	teen	0
1 ⋮	1 ⋮	cheap ⋮	cheap ⋮	1 ⋮
1	**1**			**27/30**
1	2	different	different	1
1	2	same	same	1
1	2	same	different	0
1	2	different	different	1
1 ⋮	2 ⋮	same ⋮	same ⋮	1 ⋮
1	**2**			**26/36**
1	**1+2**			**53/66**

Table 4.4 on the discrimination results included five key elements: participant number, test number, correct answer, participant's answer, and test score. The score column indicates whether a participant's answer is correct or incorrect, with a score of 1 representing a correct answer and a score of 0 representing an incorrect answer. Participants' discrimination test scores ranged from 32 to 65 (with a possible minimum of 0 and a maximum of 66). For further analysis, this range was divided into five

listening score groups based on K-means clustering in R (R Core Team 2024) : (a) Group 1: scores ranging from 32 to 39, (b) Group 2: scores ranging from 39 to 45, (c) Group 3: scores ranging from 47 to 52, (d) Group 4: scores ranging from 53 to 58, and (e) Group 5: scores ranging from 60 to 65.

All raw data from the ABX perceptual experiments was combined into a single Excel file. This data was then modified to prepare it for statistical analysis, as illustrated in Table 4.5. These modifications included cleaning the data, correcting any inconsistencies, and organizing it into a format suitable for detailed statistical analysis.

Table 4.5 Sample dataset for statistical analysis for perceived /ɨ/ epenthesis

Participant	L-score group	Word	Voicing	Release	Place	Tenseness	Epenthesis
1	4	dit	VL	R	ALV	Tense	Yes
1	4	dit̚	VL	UR	ALV	Tense	No
1	4	did	V	R	ALV	Tense	No
1	4	did̚	V	UR	ALV	Tense	Yes
1	4	dik	VL	R	VEL	Tense	Yes
1	4	dik̚	VL	UR	VEL	Tense	Yes
1	4	dig	V	R	VEL	Tense	Yes
1	4	dig̚	V	UR	VEL	Tense	No
⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮

Table 4.6 Sample dataset for statistical analysis for perceived /i/ epenthesis

Participant	L-score group	Word	Voicing	Duration	Place	Tenseness	Epenthesis
1	4	didʒː	V	L	PA	Tense	No
1	4	did͡ʒ	V	S	PA	Tense	No
1	4	ditʃː	VL	L	PA	Tense	Yes
1	4	dit͡ʃ	VL	S	PA	Tense	Yes
1	4	dɪdʒː	V	L	PA	Lax	Yes
1	4	dɪd͡ʒ	V	S	PA	Lax	No
1	4	dɪtʃː	VL	L	PA	Lax	No
1	4	dɪt͡ʃ	VL	S	PA	Lax	Yes
⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮

Tables 4.5 and 4.6 included seven elements: participant number, listening score group determined by two tense/lax discrimination tests (Group 1 for the lowest listening scores and Group 5 for the highest

listening scores), word (English X in ABX sequences), voicing (voiced vs. voiceless), release for /ɨ/ epenthesis (released vs. unreleased), noise duration for /i/ epenthesis (long vs. short), place of the final consonant (/ɨ/ epenthesis: alveolar vs. bilabial vs. velar; /i/ epenthesis: post-alveolar), tenseness of the pre-final vowel (lax vs. tense), and epenthesis (yes vs. no) indicating whether participants perceived vowel epenthesis or not.

4.3 Results

4.3.1 English tense and lax vowel discrimination tests

The first discrimination test consisted of 30 questions, and the second one consisted of 33 questions. Participants received one point for each correct answer, with a maximum possible score of 66. In these tests, the lowest score was 32 and the highest score was 65. Based on K-means clustering, the participants were divided into five groups, as shown in Figure 4.11, and the mean scores are presented in Table 4.7.

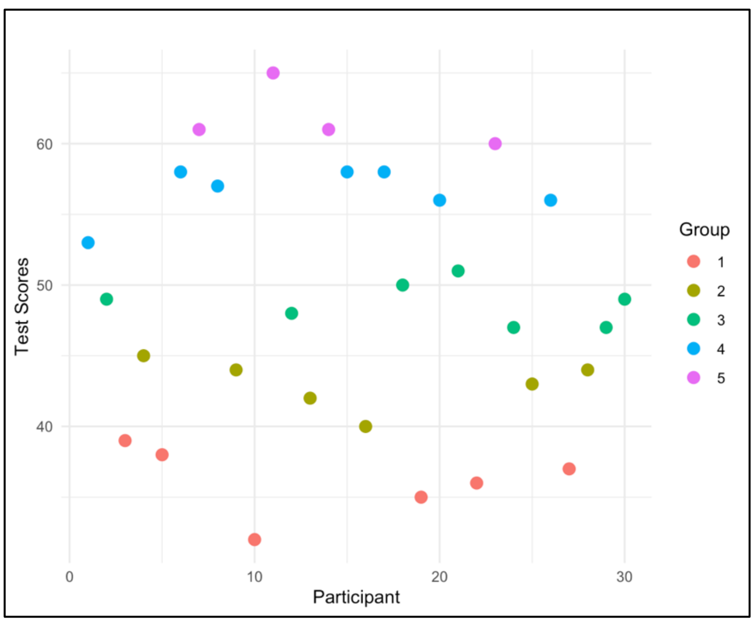

Figure 4.11 Five groups based on test scores

Table 4.7 Mean scores of the discrimination tests

	Number of participants	Score range	Mean (SD)
Group 1	6	32 ~ 39	36.2 (2.4)
Group 2	6	40 ~ 45	43.0 (1.7)
Group 3	7	47 ~ 52	48.1 (1.5)
Group 4	7	53 ~ 58	56.2 (1.8)
Group 5	4	60 ~ 65	61.3 (2.3)
All groups	30	32 ~ 65	48.9 (9.1)

In Table 4.7, discrimination test scores were classified into five groups using K-means clustering. The relatively small standard deviations within the groups suggest that the clustering effectively grouped participants with similar discrimination test performance levels.

4.3.2 ABX perceptual results

4.3.2.1 /ɨ/ epenthesis: Effects of each factor

First, the release of the final stop was investigated as a factor affecting native Koreans' perception of /ɨ/ epenthesis. The ABX perceptual results showed that when the final stop was released in an English CVC stimulus, participants tended to perceive it as more similar to a Korean CVC with epenthetic /ɨ/ than when it was unreleased, as depicted in Figure 4.12.

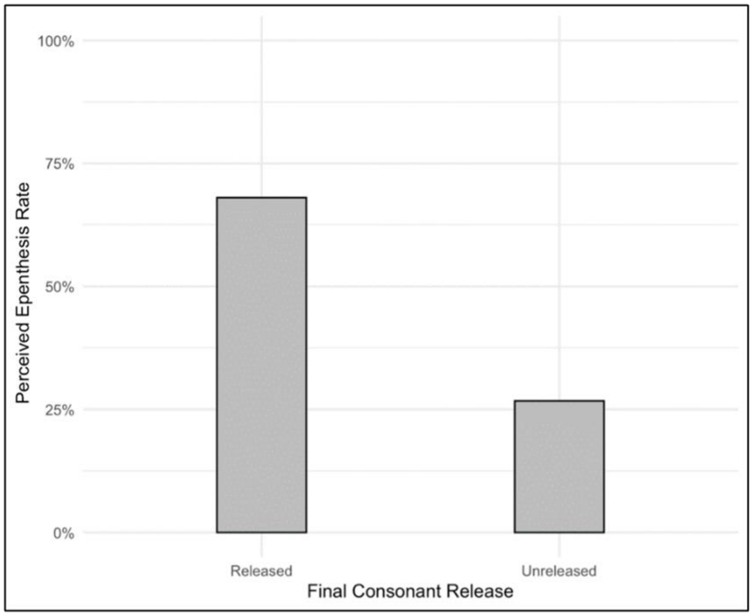

Figure 4.12 Perceived /ɨ/ epenthesis rate by release of the final consonant

Figure 4.12 presents the epenthesized stimulus rates based on whether the final stop is released or unreleased. The perceived /ɨ/ epenthesis rate is higher when the final stop is released compared to when it is unreleased. Specifically, when the final stop is released, the rate is 68.1%, whereas it is only 26.7% when the final stop is unreleased.

Second, the influence of final stop voicing on native Koreans' perception of /ɨ/ epenthesis was examined. The ABX perceptual results showed that when the final stop in an English CVC stimulus was voiced, participants were more likely to perceive it as resembling a Korean CVC with epenthetic /ɨ/ than when the final stop was voiceless, as presented in Figure 4.13 below.

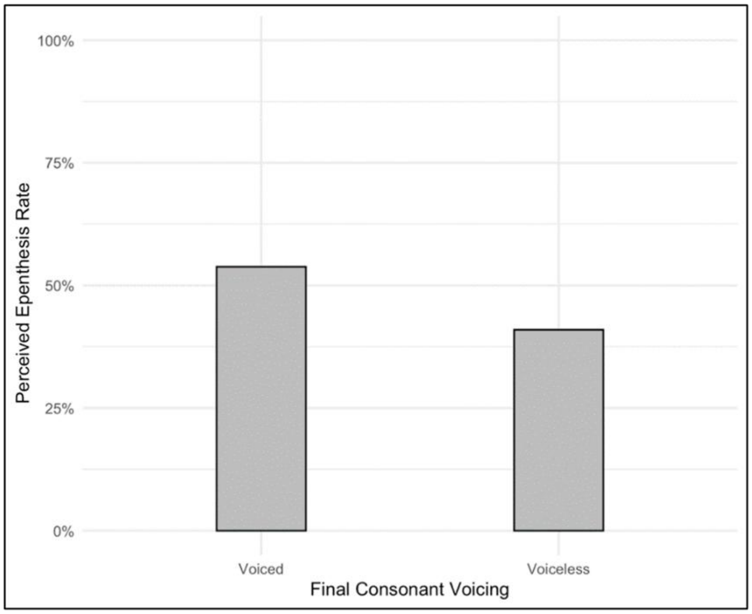

Figure 4.13 Perceived /ɨ/ epenthesis rate by voicing of the final consonant

Figure 4.13 illustrates the perceived /ɨ/ epenthesis rates based on the voicing of the final stop. The data show that the perceived epenthesis rate is higher when the final stop is voiced than when it is voiceless. Specifically, the rate is 53.8% for voiced consonants, compared to 40% for voiceless consonants.

Next, the effect of the final stop's place of articulation on native Koreans' perception of /ɨ/ epenthesis was examined. The findings indicated that participants perceived English CVC stimuli as most similar to Korean CVC forms with epenthetic /ɨ/ when the final stop was alveolar, followed by velar, and least similar when it was bilabial.

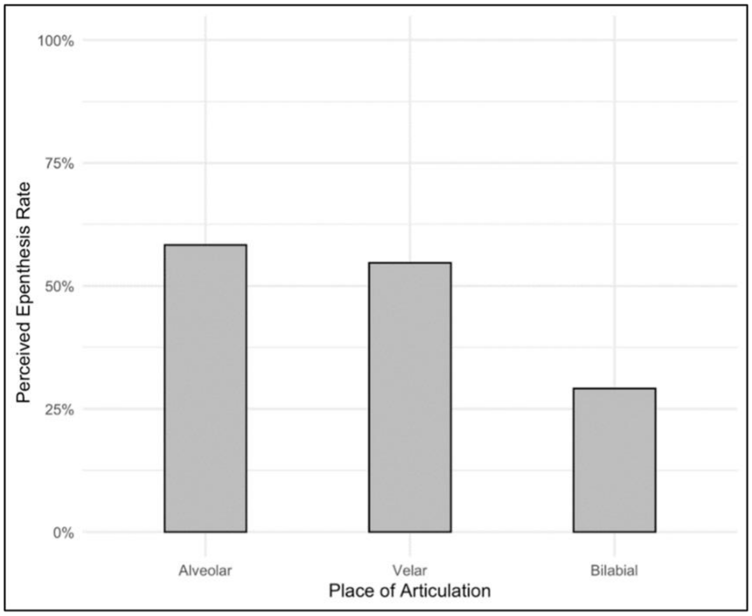

Figure 4.14 Perceived /ɨ/ epenthesis rate by place of articulation of the final consonant

Figure 4.14 shows the epenthesized stimulus rates based on the final stop's place of articulation. In this figure, participants perceived /ɨ/ epenthesis most frequently when the final stop was alveolar and least frequently when it was bilabial: 58.3% for alveolar, 54.7% for velar, and 29.2% for bilabial.

Lastly, the tenseness of the pre-final vowel was examined. The ABX perceptual results showed that participants were more likely to perceive an English CVC stimulus as similar to a Korean CVC with epenthetic /ɨ/ when the pre-final vowel was tense than when it was lax, as shown in Figure 4.15.

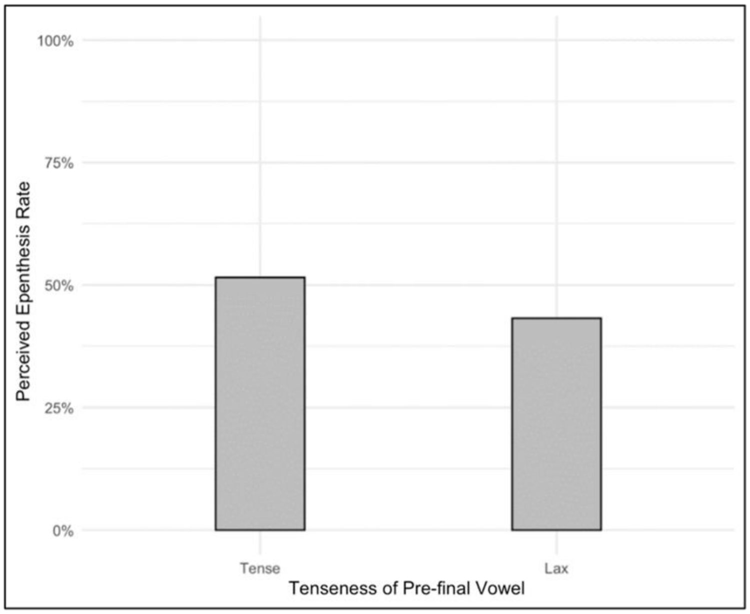

Figure 4.15 Perceived /ɨ/ epenthesis rate by tenseness of the pre-final vowel

Figure 4.15 presents the perceived /ɨ/ epenthesis rate based on the tenseness of the pre-final vowel. As shown in the figure, the perceived epenthesis rate is higher when the pre-final vowel is tense than when it is lax. Specifically, the rate is 50.7% with a pre-final tense vowel, compared to 45.3% with a pre-final lax vowel.

The descriptive analysis of each factor showed that native Korean listeners tend to perceive /ɨ/ epenthesis more often when: (a) the final stop is released, (b) the final stop is voiced, (c) the final stop is alveolar, followed by velar, and least often bilabial, and (d) the pre-final vowel is tense. Based on these observations, the statistical analysis of these factors was conducted. A mixed-effects logistic regression model was fitted using the glmer() function from the lme4 package (Bates et al. 2024) in R (R Core Team 2024), and ANOVA was used to determine the best model. This model included the following fixed effects: tenseness of the pre-final vowel (lax vs. tense), place of articulation of the final stop (alveolar vs. bilabial vs. velar), voicing of the final stop (voiced vs. voiceless), release of the final stop (released vs. unreleased), and subjects' listening scores from the tense/lax discrimination tests. The model also included interaction terms among these fixed effects to examine how they interact and influence the likelihood of /ɨ/ epenthesis. In addition to the fixed effects, the model included random effects for subject and word. The dependent variable in the statistical model was the participants' binary choice (yes vs. no) indicating whether they perceived /ɨ/ epenthesis in the given words. The statistical model results revealed that the voicing, release, and place of articulation of the final stop significantly affected the likelihood of /ɨ/ epenthesis being perceived by the subjects. Table 4.8 shows the results.

Table 4.8 The result for perceived /ɨ/ epenthesis

	Estimate	Std. Error	z value	Pr (>|z|)
(Intercept)	−2.6001	0.3564	−7.2935	<0.0001 ***
Release Released	2.0588	0.1473	13.9732	<0.0001 ***
Voicing Voiced	0.7099	0.1408	5.0410	<0.0001 ***
Tenseness Tense	0.3565	0.3423	1.0428	0.2976
Place Alveolar	1.5938	0.1793	8.8894	<0.0001 ***
Place Velar	1.3987	0.1772	7.8921	<0.0001 ***
Listening Score	0.0492	0.0663	0.7419	0.4581
Release Released:Voicing	2.0588	0.1473	13.9731	<0.0001 ***
Release Released:Place Alveolar	2.1341	0.1493	14.2877	<0.0001 ***
Release Released:Place Velar	0.9231	0.1215	7.5922	<0.0001 ***
Release Released:Tenseness Tense	−0.1018	0.1021	−0.9973	0.6171
Release Released:Listening Score	−0.1778	0.1002	−0.8925	0.3720
Voicing Voiced:Place Alveolar	0.7099	0.1408	5.0411	<0.0001 ***
Voicing Voiced:Place Velar	0.9231	0.1216	7.5920	<0.0001 ***
Voicing Voiced:Tenseness Tense	0.1962	0.1372	1.4306	0.1521
Voicing Voiced:Listening Score	−0.1478	0.1163	−1.2707	0.2038
Place Alveolar:Tenseness Tense	0.0301	0.1355	0.4044	0.6859
Place Velar:Tenseness Tense	0.0546	0.1631	0.3865	0.5391
Place Alveolar:Listening Score	0.0448	0.2090	0.2143	0.8303
Place Velar:Listening Score	−0.0239	0.0542	−0.4401	0.6598
Tenseness Tense:Listening Score	0.4347	0.0329	6.8176	<0.0001 ***

According to the statistical results presented in Table 4.8, participants perceived English nonce words as more similar to Korean nonce words with /ɨ/ epenthesis under certain conditions. Specifically, they were more likely to perceive epenthesis /ɨ/ if (a) the final stop was released ($p < 0.0001$), (b) the final stop was voiced ($p < 0.0001$), and (c) the final stop was either alveolar ($p < 0.0001$) or velar ($p < 0.0001$) with no significant difference between these two consonants, as shown in Table 4.9.

Table 4.9 Tukey's pairwise comparisons for place of articulation of the final consonant for perceived /ɨ/ epenthesis

contrast	Estimate	Std. Error	z value	Pr (>|z|)
Bilabial – Alveolar	−1.5937	0.1792	−8.8895	<0.0001 ***
Bilabial – Velar	−1.3390	0.1771	−7.5678	<0.0001 ***
Alveolar – Velar	0.1953	0.1669	1.1533	0.4728

In Table 4.9, Tukey's pairwise comparisons from the emmeans package (Lenth 2024) in R (R Core Team 2024) were used, and the results show that both alveolar and velar final stops trigger significantly more perceived /ɨ/ epenthesis than bilabial final stops (alveolar: $p < 0.0001$; velar: $p < 0.0001$). However, there is no significant difference between the perceived epenthesis rates triggered by alveolar and velar final stops ($p = 0.4728$). This suggests that while alveolar and velar stops both increase the likelihood of /ɨ/ epenthesis compared to bilabial stops, they do so to a similar degree.

In the case of the tenseness of the pre-final vowel, the descriptive analysis showed a numerical difference between the perceived /ɨ/ epenthesis rates for tense (50.7%) and lax vowels (45.3%), but the statistical analysis indicated that this difference was not significant ($p = 0.2976$) in Table 4.8. Hence, the tenseness of the pre-final vowel does not have a significant effect on native Korean listeners' perception of /ɨ/ epenthesis. Also, in Table 4.8 participants' listening scores on tense/lax discrimination tests do not influence native Korean listeners' perception of /ɨ/ epenthesis ($p = 0.4581$).

4.3.2.2 /ɨ/ epenthesis: Interactions between factors

4.3.2.2.1 Release and voicing

The release and voicing of the final consonant show a significant interaction ($p < 0.0001$) in Table 4.8. If the final stop is released and voiced, the epenthesized stimulus rate is 67%, whereas it is 69.1% if the consonant is released and voiceless. Conversely, when the final stop is unreleased and voiced, the perception of epenthesis occurs 40.5% of the time, and only 12.9% when it is unreleased and voiceless, as shown in Figure 4.16.

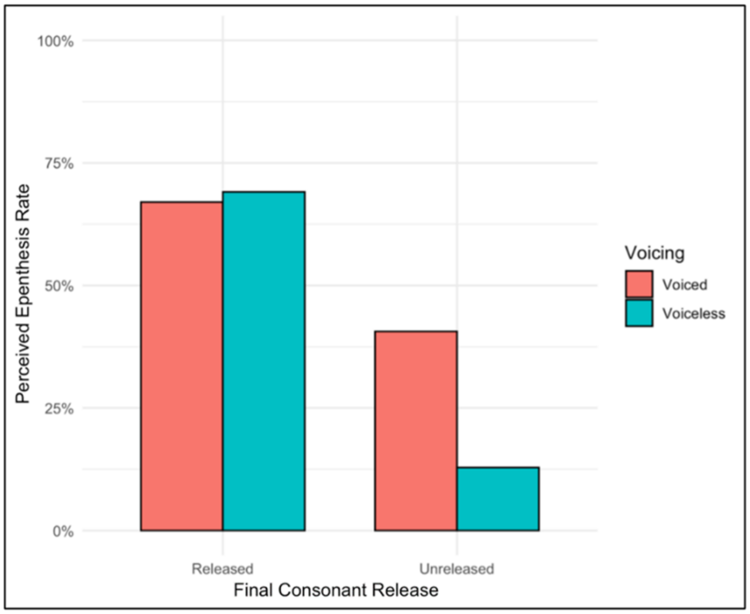

Figure 4.16 Perceived /ɨ/ epenthesis rate by release and voicing of the final consonant

Table 4.10 Tukey's pairwise comparisons for the interaction between release and voicing of the final consonant for perceived /ɨ/ epenthesis

contrast	Estimate	Std. Error	z value	Pr (>|z|)
Released Voiceless – Released Voiced	−0.0107	0.1412	−0.0758	0.9389
Unreleased Voiceless – Unreleased Voiced	−1.6891	0.2241	−7.5373	<0.0001 ***
Unreleased Voiceless – Released Voiceless	−3.0639	0.2350	−13.0379	<0.0001 ***
Unrelease Voiced – Released Voiced	−1.2627	0.1896	−6.6598	<0.0001 ***
Released Voiceless – Unreleased Voiced	1.3753	0.1915	7.1817	<0.0001 ***
Unreleased Voiceless – Released Voiced	−2.9532	0.2338	−12.6313	<0.0001 ***

In Table 4.10, based on Tukey's pairwise comparisons, the effect of release was significant for both voiceless and voiced stops. This indicates that participants perceived the English CVC stimuli as more similar to a Korean CVC with /ɨ/ epenthesis when the final stop was released, compared to when it was unreleased, regardless of the voicing of the final stop. This suggests that the release of the final stop is a crucial factor in native Korean listeners' perception of /ɨ/ epenthesis, enhancing the similarity between English and Korean forms. In contrast, the voicing of the final stop showed different patterns depending on whether the final stop was released or unreleased. Voicing did not have any significant effect on the perception of /ɨ/ epenthesis when the final stop was released (p = 0.9389). However, the effect of voicing was significant when the final stop was unreleased ($p < 0.0001$). This means that for unreleased final stops, participants were more likely to perceive /ɨ/ epenthesis if the consonant was voiced rather than voiceless.

4.3.2.2.2 Release and place of articulation

There was a significant interaction between the release and the place of articulation of the final consonant (alveolar: $p < 0.0001$; velar: $p < 0.0001$) in Table 4.8. If the final stop is a released alveolar or released velar, /ɨ/ epenthesis is perceived in 72.4% and 68.7% of cases, respectively, whereas it happens in only 40.6% of cases if the final stop is a released bilabial. In the case of unreleased consonants, they show significantly lower perceived /ɨ/ epenthesis rates than their released counterparts. Specifically, if the final stop is unreleased alveolar, unreleased velar, or unreleased bilabial, /ɨ/ epenthesis is perceived in 25.5%, 27.6%, and 17.2% of cases, respectively in Figure 4.17.

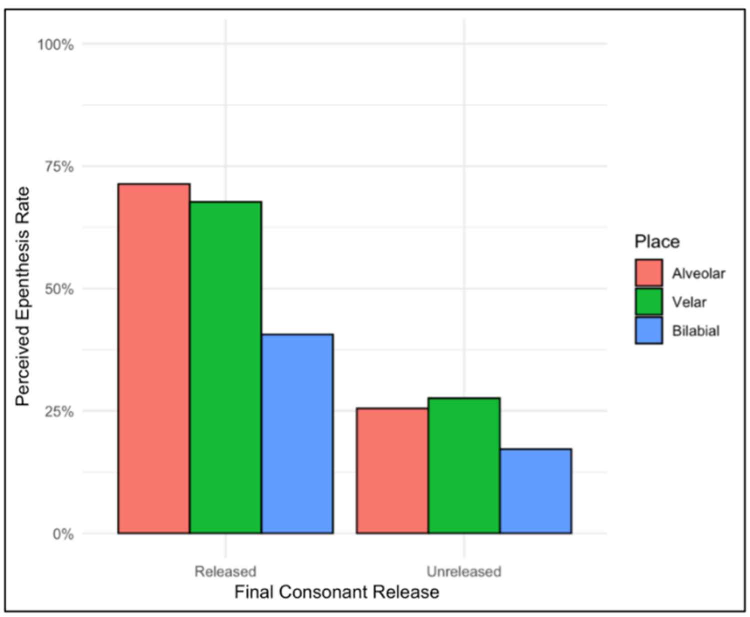

Figure 4.17 Perceived /ɨ/ epenthesis rate by release and place of articulation of the final consonant

Table 4.11 Tukey's pairwise comparisons for the interaction between release and place of articulation of the final consonant for perceived /ɨ/ epenthesis

contrast	Estimate	Std. Error	z value	Pr (>|z|)
Unreleased Bilabial – Released Bilabial	−2.0587	0.1472	−13.9857	<0.0001 ***
Unreleased Alveolar – Released Alveolar	−1.8645	0.2190	−8.5137	<0.0001 ***
Unreleased Velar – Released Velar	−1.3989	0.1771	−7.8989	<0.0001 ***
Unreleased Bilabial – Unreleased Alveolar	−0.6601	0.2032	−3.2485	<0.0001 ***
Unreleased Bilabial – Unreleased Velar	−0.4649	0.2001	−2.3233	<0.0001 ***
Unreleased Alveolar – Unreleased Velar	−0.4013	0.2193	−2.9854	0.0656
Released Bilabial – Released Alveolar	−3.6529	0.2599	−14.0551	<0.0001 ***
Released Bilabial – Released Velar	−1.5941	0.1786	−8.9255	<0.0001 ***
Released Alveolar – Released Velar	0.1952	0.1675	1.1654	0.0927

In Table 4.11, Tukey's pairwise comparisons show that released velar, alveolar, and bilabial stops result in significantly more perceived /ɨ/ epenthesis than their unreleased counterparts. This indicates that /ɨ/ epenthesis is significantly more likely to be perceived when the final stop is released, regardless of the final stop's place of articulation. Furthermore, among the different places of articulation, alveolar and velar stops cause more perceived /ɨ/ epenthesis than bilabial stops in both released and unreleased conditions. Specifically, when the final stop is either alveolar or velar, the perceived epenthesis rate is higher compared to when the final stop is bilabial. This pattern holds true regardless of whether the consonant is released or unreleased, demonstrating the consistent influence of place of articulation on the likelihood of perceived /ɨ/ epenthesis. Importantly, there is no significant difference between the rates of perceived /ɨ/ epenthesis caused by alveolar stops compared to velar stops, suggesting that these two types of consonants have a similar impact on the occurrence of perceived /ɨ/ epenthesis in both release conditions (released: $p = 0.0927$; unreleased: $p = 0.0656$).

4.3.2.2.3 Release and vowel tenseness

The release of the final consonant and the tenseness of the pre-final vowel did not show any significant interaction ($p = 0.6171$) in Table 4.8. If the final stop is released, the perceived epenthesis rates are observed to be 59.7% for lax vowels and 60.1% for tense vowels. Conversely, when the final stop is unreleased, the perceived epenthesis rates drop significantly to 20.1% for lax vowels and 23.3% for tense vowels in Figure 4.18.

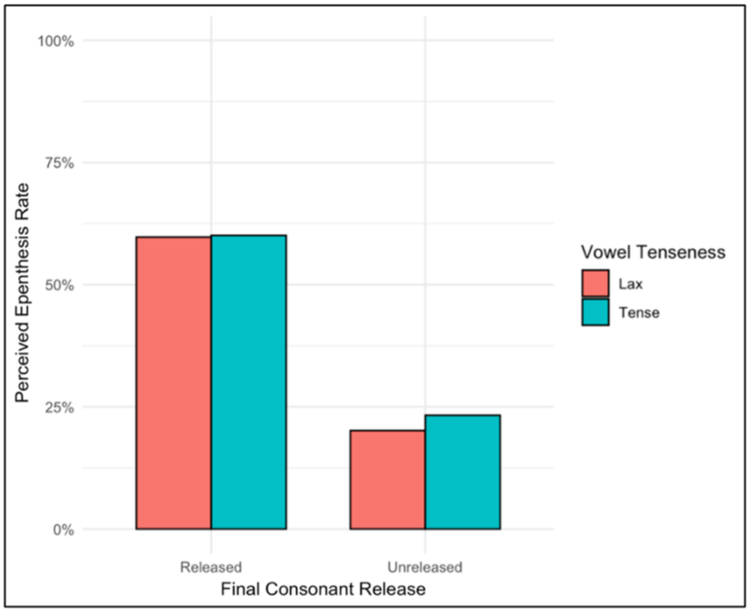

Figure 4.18 Perceived /ɨ/ epenthesis rate by release of the final consonant and the tenseness of the pre-final vowel

Table 4.12 Tukey's pairwise comparisons for the interaction between release of the final consonant and the tenseness of the pre-final vowel for perceived /ɨ/ epenthesis

contrast	Estimate	Std. Error	z value	Pr (>|z|)
Unreleased Lax – Released Lax	−2.0597	0.1402	−14.6912	<0.0001 ***
Unreleased Lax – Unreleased Tense	−0.4151	0.2119	−1.9589	0.0621
Unreleased Lax – Released Tense	−2.5198	0.1932	−13.0424	<0.0001 ***
Released Lax – Unreleased Tense	1.6003	0.2071	7.7273	<0.0001 ***
Released Lax – Released Tense	−0.2739	0.1769	−1.5483	0.1222
Unreleased Tense – Released Tense	−2.4401	0.0930	−26.2379	<0.0001 ***

As shown in Table 4.12, regardless of the tenseness of the pre-final vowel, the perceived /ɨ/ epenthesis rates are statistically higher when the final stop is released compared to when it is unreleased (tense: $p < 0.0001$; lax: $p < 0.0001$). However, there was no significant difference between tense and lax vowels in both the released ($p = 0.1222$) and unreleased ($p = 0.0621$) conditions. This suggests that while the release of the final stop greatly affects the likelihood of perceived /ɨ/ epenthesis rate, the tenseness of the pre-final vowel does not have a significant impact in either condition.

4.3.2.2.4 Voicing and place of articulation

In Table 4.8, a significant interaction was found between the voicing and the place of articulation of the final consonant ($p < 0.0001$). If the final stop is voiced, the perceived /ɨ/ epenthesis rates are 70.9% for alveolars, 61.5% for velars, and 28.9% for bilabials. Conversely, with a final voiceless consonant, the epenthesized stimulus rates are 44.8% for alveolars, 48.8% for velars, and 29.7% for bilabials in Figure 4.19.

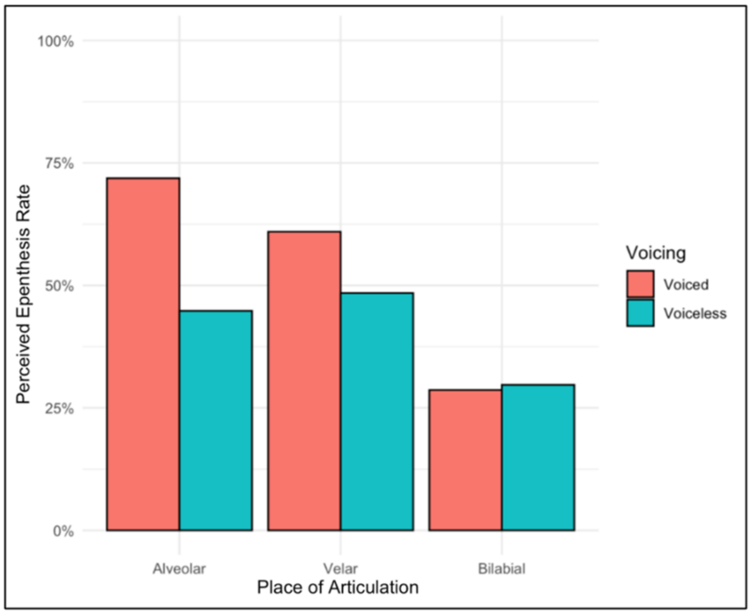

Figure 4.19 Perceived /ɨ/ epenthesis rate by place of articulation and voicing of the final consonant

Table 4.13 Tukey's pairwise comparisons for the interaction between place of articulation and voicing of the final consonant for perceived /ɨ/ epenthesis

contrast	Estimate	Std. Error	z value	Pr (>|z|)
Voiceless Bilabial – Voiceless Velar	−0.5141	0.2193	−2.3443	0.0178 *
Voiced Bilabial – Voiceless Bilabial	−0.0457	0.1794	−0.2547	0.7950
Voiceless Alveolar – Voiceless Velar	−0.3112	0.2183	−1.4256	0.1526
Voiced Bilabial – Voiced Velar	−1.3989	0.1211	−11.5516	<0.0001 ***
Voiced Alveolar – Voiced Velar	0.1764	0.0938	1.8806	0.0773
Voiced Velar –Voiceless Velar	0.7109	0.1416	5.0205	<0.0001 ***
Voiced Alveolar – Voiceless Alveolar	0.6119	0.1574	3.8875	<0.0001 ***

According to Tukey's pairwise comparisons in Table 4.13, alveolar and velar stops consistently induce more /ɨ/ epenthesis perception than bilabial stops, regardless of whether the final stop is voiced or voiceless. Additionally, there is an interaction between the voicing condition and bilabial stops. When the final stop is either a voiced alveolar or a voiced velar, perceived /ɨ/ epenthesis occurs more frequently compared to when the final stop is the corresponding voiceless one. However, in the case of final bilabial stops, there is no significant difference between voiced and voiceless conditions ($p = 0.7950$). This suggests that while the voicing of alveolar and velar stops significantly impacts the perception of /ɨ/ epenthesis, the voicing of bilabial stops does not have a similar effect.

4.3.2.2.5 Voicing and vowel tenseness

The interaction between the voicing of the final consonant and the tenseness of the pre-final vowel was not statistically significant ($p = 0.1521$) in Table 4.8. When the final stop is voiced, the /ɨ/ epenthesis perception rate is observed to be 58.7% for tense vowels and 57.5% for lax vowels. When the final stop is voiceless, the rates are 43.8% for tense vowels and 38.5% for lax vowels in Figure 4.20.

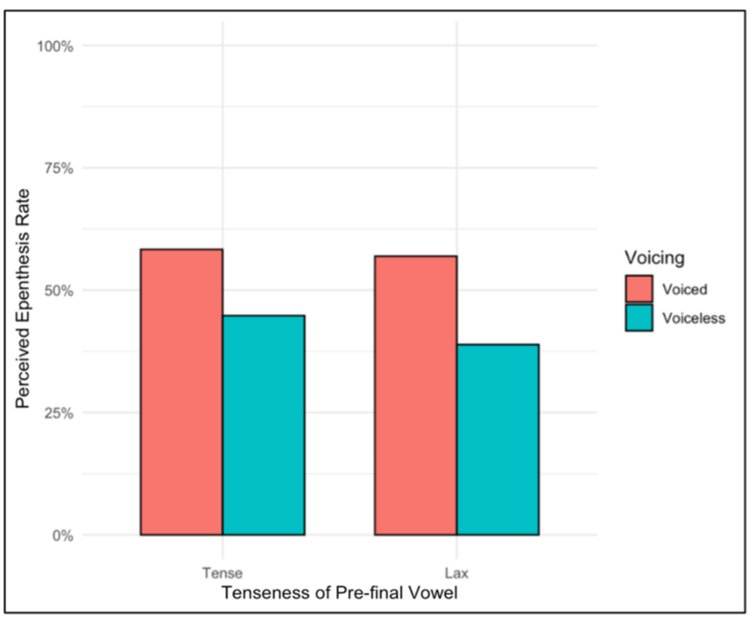

Figure 4.20 Perceived /ɨ/ epenthesis rate by voicing of the final consonant and the tenseness of the pre-final vowel

Table 4.14 Tukey's pairwise comparisons for the voicing of the final consonant and the tenseness of the pre-final vowel for perceived /ɨ/ epenthesis

contrast	Estimate	Std. Error	z value	Pr (>|z|)
Voiced Lax – Voiced Tense	−0.1957	0.1372	−1.4264	0.1520
Voiced Lax – Voiceless Lax	0.8363	0.1391	6.0122	<0.0001 ***
Voiced Tense – Voiceless Tense	0.4973	0.1319	3.7703	<0.0001 ***
Voiceless Lax – Voiceless Tense	−0.2829	0.1575	−1.7962	0.0722
Voiced Lax – Voiceless Tense	0.4011	0.1522	2.6353	0.0081 **
Voiceless Lax – Voiced Tense	−0.1226	0.0310	−3.9548	<0.0001 ***

In Table 4.14, Tukey's pairwise comparisons reveal that, regardless of whether the pre-final vowel is tense or lax, the likelihood of /ɨ/ epenthesis perception is higher when the final stop is voiced compared to when it is voiceless (tense: $p < 0.0001$; lax: $p < 0.0001$). This tendency suggests that the voicing of the final stop plays a more crucial role in promoting the perception of /ɨ/ epenthesis than the tenseness of the pre-final vowel. Moreover, statistical analysis reveals no significant differences in the perception of /ɨ/ epenthesis between tense and lax vowels across both voicing conditions. Specifically, in the voiced condition, the difference is not significant ($p = 0.1520$), and similarly, in the voiceless condition, no significant difference is observed ($p = 0.0722$).

4.3.2.2.6 Place of articulation and vowel tenseness

No significant interaction was found between the place of articulation of the final consonant and the tenseness of the pre-final vowel (alveolar: $p = 0.6859$; velar: $p = 0.5391$) in Table 4.8. When the pre-final vowel is lax, /ɨ/ epenthesis perception occurs in 57.8% of cases for final alveolars, 55.2% for final velars, and 31.7% for final bilabials. On the other hand, when the pre-final vowel is tense, the perceived /ɨ/ epenthesis rates are slightly different, occurring in 58.9% of cases for final alveolars, 50.5% for final velars, and 37.5% for final bilabials in Figure 4.21.

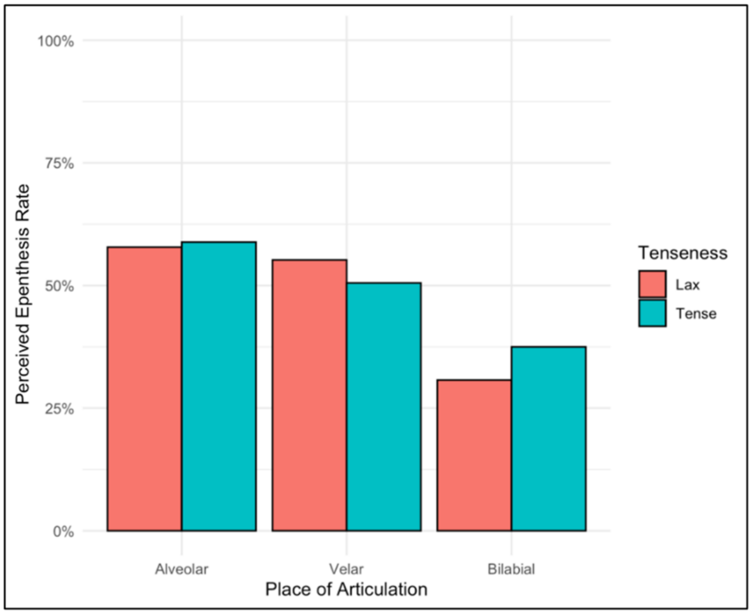

Figure 4.21 Perceived /ɨ/ epenthesis rate by place of articulation of the final consonant and tenseness of the pre-final vowel

Table 4.15 Tukey's pairwise comparisons for the place of articulation of the final consonant and the tenseness of the pre-final vowel for perceived /ɨ/ epenthesis

contrast	Estimate	Std. Error	z value	Pr (>|z|)
Lax Alveolar - Tense Alveolar	−0.0538	0.1352	−0.3979	0.6850
Lax Alveolar - Lax Bilabial	1.2453	0.1709	7.2867	<0.0001 ***
Lax Alveolar - Lax Velar	0.2781	0.1632	1.7040	0.0880
Tense Alveolar - Tense Bilabial	1.3002	0.2171	5.9889	<0.0001 ***
Tense Alveolar - Tense Velar	0.2338	0.1629	1.4352	0.1497
Lax Bilabial - Tense Bilabial	−0.0537	0.1263	−0.4251	0.6930
Lax Bilabial - Lax Velar	−0.9668	0.1684	−5.7411	<0.0001 ***
Tense Bilabial - Tense Velar	−0.8119	0.1548	−5.2448	<0.0001 ***
Lax Velar - Tense Velar	−0.0534	0.2641	−0.2023	0.6110

As shown in Tukey's pairwise comparisons in Table 4.15, the perception of /ɨ/ epenthesis is consistently more likely to occur with final alveolar or velar stops than with bilabial stops, regardless of the tenseness of the pre-final vowel. Furthermore, the difference in /ɨ/ epenthesis perception rates between tense and lax vowels is not statistically significant for any of the places of articulation: alveolar stops (p = 0.6850), bilabial stops (p = 0.6930), and velar stops (p = 0.6110). Consequently, these results indicate that there is no significant interaction between the final stop's place of articulation and the tenseness of the pre-final vowel in influencing the likelihood of /ɨ/ epenthesis perception.

4.3.2.2.7 Listening score and vowel tenseness

Even though neither the listening score groups based on two lax/tense discrimination tests nor the tenseness of the pre-final vowel had any significant effects on /ɨ/ epenthesis perception (listening score: $p = 0.4581$; tenseness: $p = 0.2976$) in Table 4.8, their interaction reveals interesting results. First, Figure 4.22 shows the perceived /ɨ/ epenthesis rates for the five listening score groups when the pre-final vowel is tense.

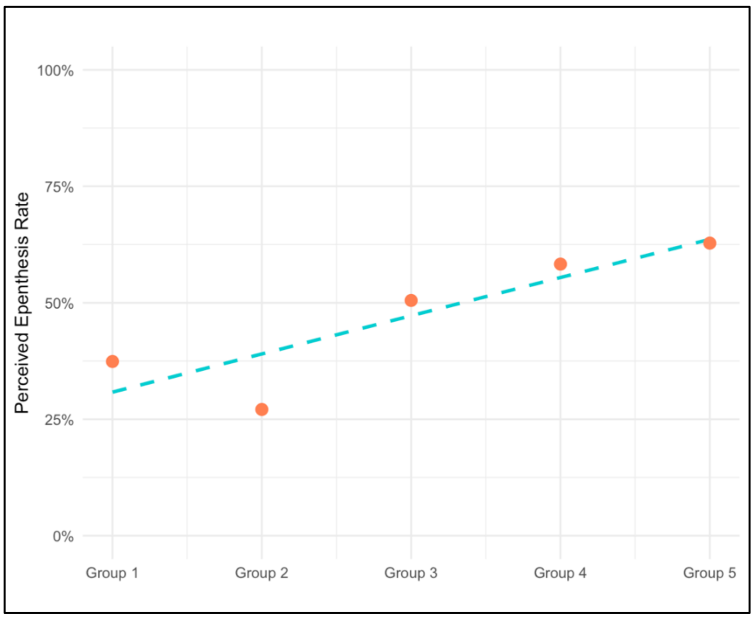

Figure 4.22 Perceived /ɨ/ epenthesis rate based on listening scores in the pre-final tense vowel condition

When the pre-vowel is tense, Listening Score Group 1 (the lowest listening score group) perceives /ɨ/ epenthesis in 37.4% of cases. In Group 2, this proportion drops to 27.1%. Group 3 shows an increase to 50.5%, followed by Group 4 at 58.3%. Finally, Group 5 (the highest listening score group) exhibits the highest proportion, with 62.8% perceiving /ɨ/ epenthesis.

The statistical analysis in Table 4.8 reveals a significant positive relationship between the tenseness of the pre-final vowel and listening scores ($p < 0.0001$). To streamline the discussion, a portion of the results from Table 4.8 is reproduced in Table 4.16.

Table 4.16 Interaction of tenseness of the pre-final vowel and listening scores for perceived /ɨ/ epenthesis

	Estimate	Std. Error	z value	Pr (>|z|)
(Intercept)	−2.6001	0.3564	−7.2935	<0.0001 ***
Tenseness Tense	0.3565	0.3423	1.0428	0.2976
Listening Score	0.0492	0.0663	0.7419	0.4581
Tenseness Tense:Listening Score	0.4347	0.0329	6.8176	<0.0001 ***

Specifically, the data show that as listening scores increase, the likelihood of /ɨ/ epenthesis perception also rises when the pre-final vowel is tense. In other words, individuals with higher listening scores are more prone to perceiving /ɨ/ epenthesis in the context of a tense pre-final vowel. This positive interaction highlights the crucial role of the ability to discriminate between English tense and lax vowels in the perceptual process of /ɨ/ epenthesis.

4.3.2.3 /i/ epenthesis: Effects of each factor

First, the noise duration of the final consonant was analyzed as a factor influencing native Koreans' perception of /i/ epenthesis. The ABX perceptual results revealed that when the noise duration of the final consonant was longer, participants were more likely to perceive it as resembling a Korean CVC form with epenthetic /i/, as shown in Figure 4.23.

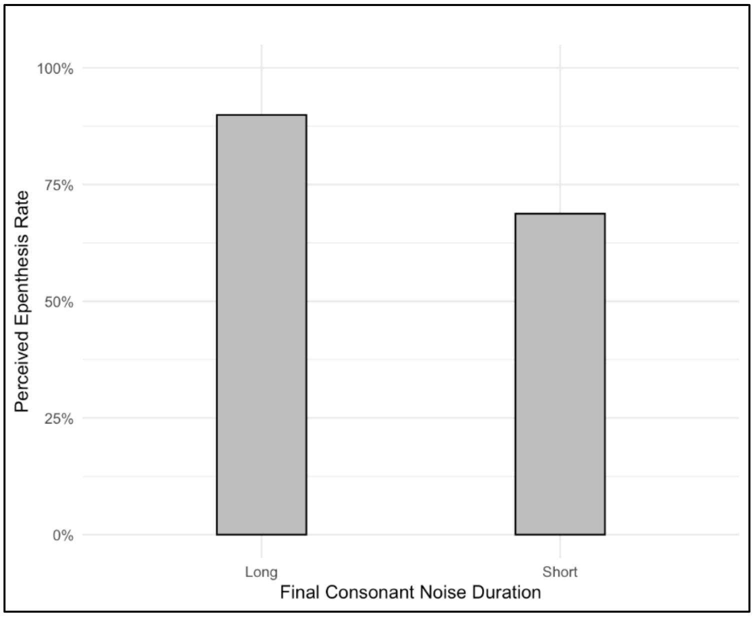

Figure 4.23 Perceived /i/ epenthesis rate by noise duration of the final consonant

Figure 4.23 displays the perceived /i/ epenthesis rate based on the noise duration of the final consonant. The perceived epenthesis rate is higher when the noise duration of the final consonant is longer. Specifically, the rate reaches 89.9% with a long noise duration, while it drops to just 68.7 with a short noise duration.

Secondly, the impact of final consonant voicing on native Koreans' perception of /i/ epenthesis was investigated. The ABX perceptual results showed that participants tended to perceive an English CVC stimulus as more similar to a corresponding Korean CVC with epenthetic /i/ when the final consonant was voiced compared to when it was voiceless, as illustrated in Figure 4.24.

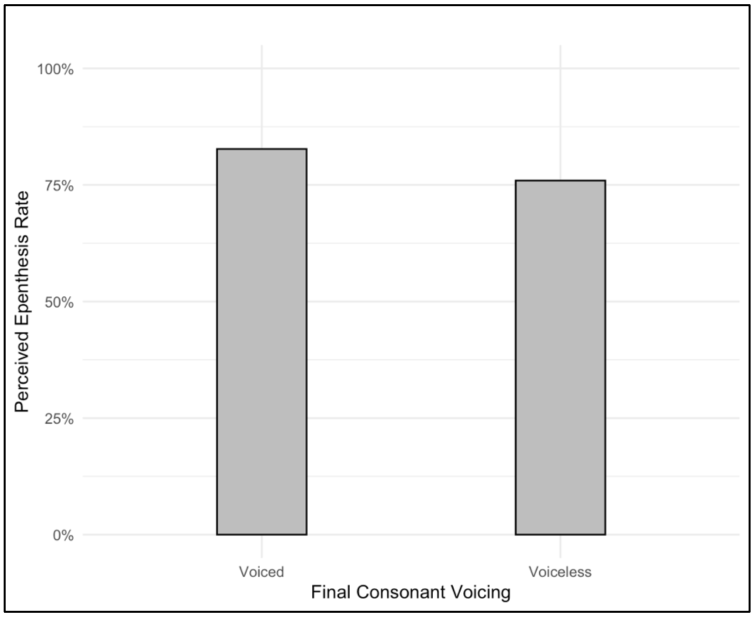

Figure 4.24 Perceived /i/ epenthesis rate by voicing of the final consonant

Figure 4.24 shows the perceived /i/ epenthesis rates according to the voicing of the final consonant. The result indicates that the perceived epenthesis rate is higher for voiced consonants than for voiceless ones, with rates of 82.7% and 75.9%, respectively.

Finally, the effect of the tenseness of the pre-final vowel was examined. The ABX perceptual results demonstrated that participants were more likely to perceive an English CVC stimulus as resembling a Korean CVC form with epenthetic /i/ when the pre-final vowel was tense rather than lax, as presented in Figure 4.25.

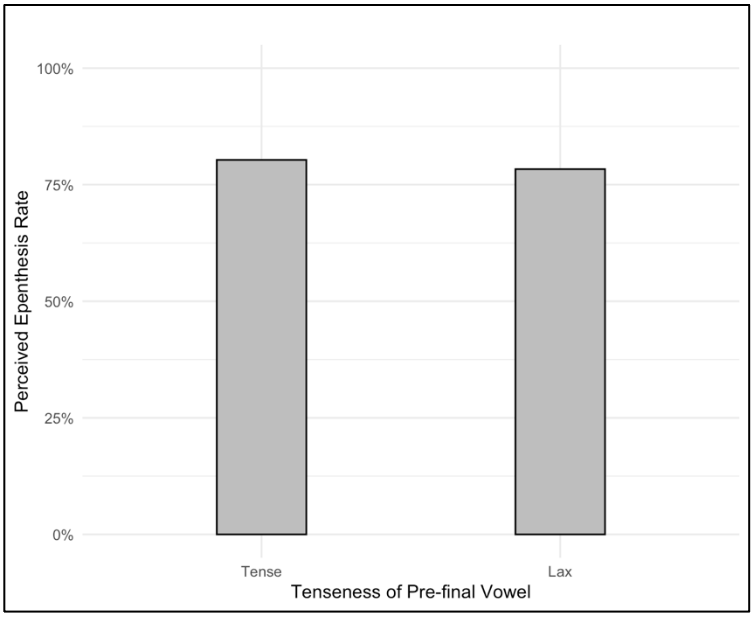

Figure 4.25 Perceived /i/ epenthesis rate by tenseness of the pre-final vowel

Figure 4.25 illustrates the perceived /i/ epenthesis rates based on the tenseness of the pre-final vowel. The data show that the perceived epenthesis rate is higher when the pre-final vowel is tense rather than lax. Specifically, the rate is 80.3% for the pre-final tense vowel, compared to 78.4% for the pre-final lax vowel.

The descriptive analysis for each factor indicated that native Korean listeners are more likely to perceive /i/ epenthesis when: (a) the noise duration of the final consonant is longer, (b) the final consonant is voiced, and (c) the pre-final vowel is tense. To investigate whether these findings are statistically meaningful, a mixed-effects logistic regression model was performed using the glmer() function. The best model based on ANOVA incorporated four fixed effects: pre-final vowel tenseness (lax vs. tense), final consonant voicing (voiced vs. voiceless), final consonant noise duration (long vs. short), and subjects' listening scores from tense/lax discrimination tests. In addition, the model incorporated interaction terms to examine how these variables interact and influence /i/ epenthesis. Random effects for subject and word were also included in the model. The dependent variable was the subjects' binary decision (yes vs. no) regarding their perception of /i/ epenthesis in the given nonce words.

The statistical analysis shows significant effects of the voicing and noise duration of the final consonant on the likelihood of perceiving /i/ vowel epenthesis, as shown in Table 4.18.

Table 4.17 The result for perceived /i/ epenthesis

	Estimate	Std. Error	z value	Pr (>|z|)
(Intercept)	1.2891	0.1449	8.8922	<0.0001 ***
Duration Long	0.3985	0.0505	7.8923	<0.0001 ***
Voicing Voiced	0.2287	0.0762	2.9987	0.0027 **
Tenseness Tense	0.1307	0.1173	1.1136	0.2650
Listening Score	0.0019	0.0021	0.9048	0.3655
Duration Long:Voicing Voiced	0.3186	0.0501	6.3480	0.0078 **
Duration Long:Tenseness Tense	0.0451	0.1253	0.3602	0.7075
Duration Long:Listening Score	−0.0329	0.0227	−1.4470	0.1486
Voicing Voiced:Tenseness Tense	−0.0480	0.1114	−0.4315	0.4718
Voicing Voiced:Listening Score	−0.0628	0.0586	−1.0711	0.2839
Tenseness Tense:Listening Score	0.0104	0.0071	1.4630	0.1433

Table 4.17 indicates that participants were more likely to perceive English nonce words as similar to their Korean counterparts with epenthetic /i/ under specific conditions. The likelihood of perceiving /i/ epenthesis increased when (a) the noise duration of the final consonant was longer ($p < 0.0001$) and (b) the final consonant was voiced ($p = 0.0027$). On the other hand, the tenseness of the pre-final vowel and listening scores did not have any significant effect (tenseness: $p = 0.2650$; listening score: $p = 0.3655$) on the perception of /i/ epenthesis.

4.3.2.4 /i/ epenthesis: Interactions between factors

4.3.2.4.1 Noise duration and voicing

In Table 4.17, a significant interaction was observed between the noise duration and voicing of the final consonant ($p = 0.0078$). When the final consonant is voiced and has a long noise duration, the epenthesis rate is 92.1%, compared to 87.5% when it is voiceless and has a long noise duration. In contrast, when the final consonant is voiced and has a short noise duration, the rate drops to 73.1%, and when it is voiceless and has a short noise duration, the rate falls to 64.4%, as shown in Figure 4.26.

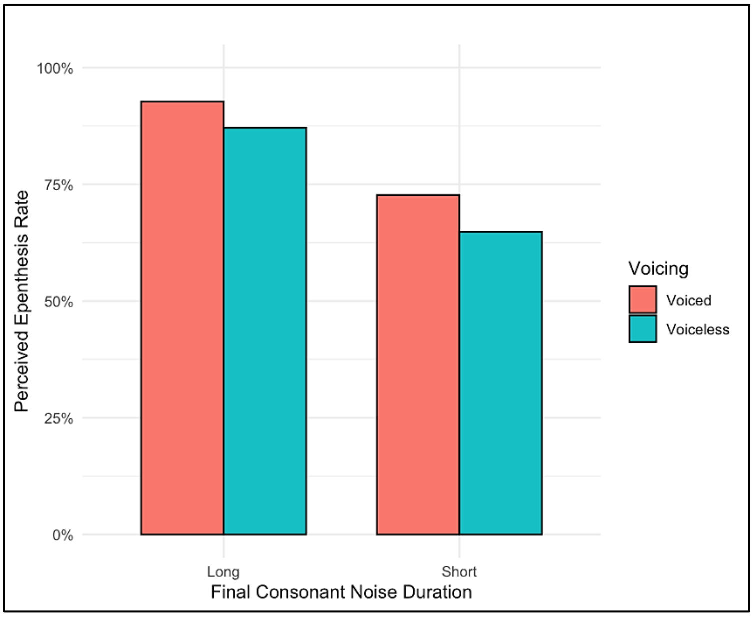

Figure 4.26 Perceived /i/ epenthesis rate by noise duration and voicing of the final consonant

Table 4.18 Tukey's pairwise comparisons for the interaction between noise duration and voicing of the final consonant for perceived /i/ epenthesis

contrast	Estimate	Std. Error	z value	Pr (>|z|)
Long Voiced - Short Voiced	1.5633	0.2032	7.6934	<0.0001 ***
Long Voiced - Long Voiceless	0.6341	0.2221	2.8551	0.0623
Long Voiced - Short Voiceless	1.9338	0.2004	9.6497	<0.0001 ***
Short Voiced - Long Voiceless	−0.9293	0.1702	−5.4601	<0.0001 ***
Short Voiced - Short Voiceless	0.3702	0.1406	2.6330	0.0212 *
Long Voiceless - Short Voiceless	1.2996	0.1669	7.7867	<0.0001 ***

In Table 4.18, Tukey's pairwise comparisons show that the noise duration of the final consonant affected both voiceless and voiced stops. Specifically, participants were more likely to perceive /i/ epenthesis when when the final consonant had a long noise duration, regardless of its voicing. This finding suggests that the noise duration of the final consonant plays a significant role in native Korean listeners' perception of /i/ epenthesis. In contrast, the voicing of the final consonant exhibited different effects depending on whether the final consonant had a long or short noise duration. Voicing did not significantly impact the perception of /i/ epenthesis when the consonant had a long noise duration (p = 0.0623). However, when the final consonant had a short noise duration, voicing had a significant effect (p = 0.0212), with participants more likely to perceive /i/ epenthesis when the consonant was voiced rather than voiceless.

4.3.2.4.2 Noise duration and vowel tenseness

There was no significant interaction between the noise duration of the final consonant and the tenseness of the pre-final vowel (p = 0.7075) in Table 4.17. When the final consonant had a long noise duration, the perceived /i/ epenthesis rates were 91% for tense vowels and 88.9% for lax vowels. However, when it had a shorter noise duration, the rates of perceived epenthesis decreased to 69.5% for tense vowels and 67.9% for lax vowels, as presented in Figure 4.27.

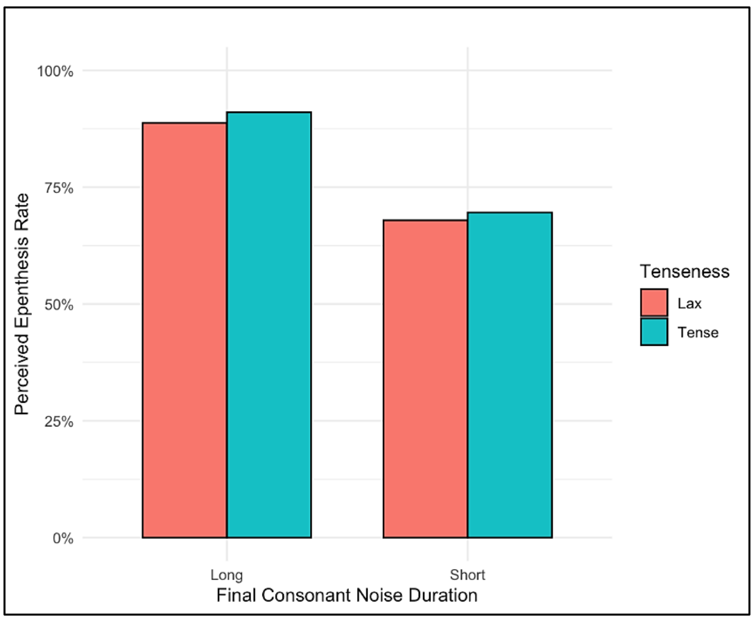

Figure 4.27 Perceived /i/ epenthesis rate by noise duration of the final consonant and tenseness of the pre-final vowel

Table 4.19 Tukey's pairwise comparisons for the interaction between noise duration of the final consonant and tenseness of the pre-final vowel for perceived /i/ epenthesis

contrast	Estimate	Std. Error	z value	Pr (>|z|)
Long Lax - Short Lax	1.3153	0.1402	9.3816	<0.0001 ***
Long Lax - Long Tense	−0.2527	0.2121	−1.1914	0.1420
Long Lax - Short Tense	1.2376	0.1935	6.3958	<0.0001 ***
Short Lax - Long Tense	−1.5671	0.2072	−7.5632	<0.0001 ***
Short Lax - Short Tense	−0.0769	0.1778	−0.4326	0.0944
Long Tense - Short Tense	−1.1590	0.0972	−11.9241	<0.0001 ***

In Table 4.19, Tukey's pairwise comparisons indicate that perceived /i/ epenthesis rates are higher when the final consonant has a longer noise duration, regardless of the tenseness condition (tense: $p < 0.0001$; lax: $p < 0.0001$). On the other hand, there is no significant difference between tense and lax vowels in either the long ($p = 0.1420$) or short ($p = 0.0944$) noise duration conditions. This suggests that while the noise duration of the final consonant significantly influences the likelihood of /i/ epenthesis perception, the tenseness of the pre-final vowel has no significant effect in either condition.

4.3.2.4.3 Voicing and vowel tenseness

No significant interaction was observed between the voicing of the final consonant and the tenseness of the pre-final vowel ($p = 0.4718$), as shown in Table 4.17. The perceived /i/ epenthesis rate is 84.3% for tense vowels and 82.8% for lax vowels when the final consonant is voiced. In contrast, for voiceless final consonant, the rates are 77.4% for tense vowels and 74.9% for lax vowels.

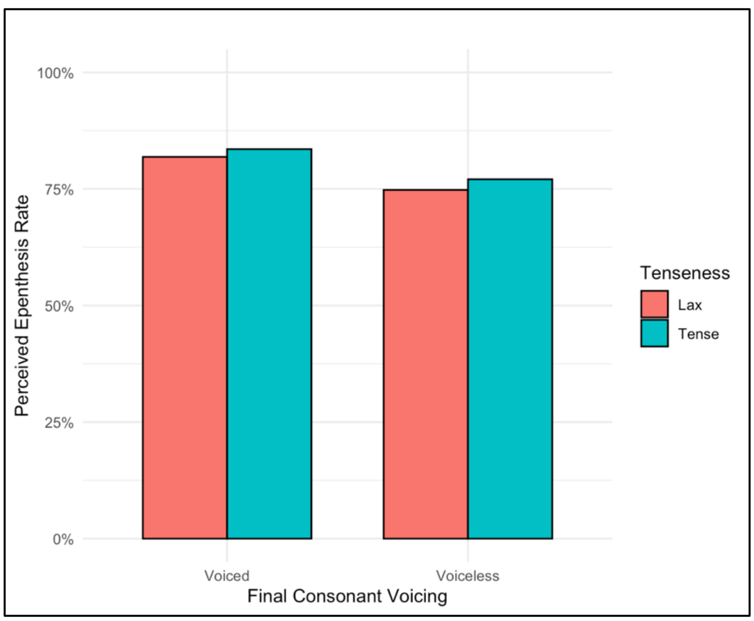

Figure 4.28 Perceived /i/ epenthesis rate by voicing of the final consonant and tenseness of the pre-final vowel

Table 4.20 Tukey's pairwise comparisons for the interaction between voicing of the final consonant and tenseness of the pre-final vowel for perceived /i/ epenthesis

contrast	Estimate	Std. Error	z value	Pr (>|z|)
Voiced Lax - Voiceless Lax	0.4203	0.1582	2.6568	0.0078 **
Voiced Lax - Voiced Tense	−0.1176	0.1712	−0.6869	0.4940
Voiced Lax - Voiceless Tense	0.2952	0.1609	1.8347	0.0671
Voiceless Lax - Voiced Tense	−0.5369	0.1624	−3.3060	<0.0001 ***
Voiceless Lax - Voiceless Tense	−0.1248	0.1505	−0.8291	0.4047
Voiced Tense - Voiceless Tense	0.4115	0.1641	2.5076	0.0122 *

Based on Tukey's pairwise comparisons in Table 4.20, /i/ epenthesis is more likely to be perceived when the final consonant is voiced, regardless of the tenseness of the pre-final vowel (lax: $p = 0.0078$; tense: $p = 0.0122$). This suggests that the voicing of the final consonant has a significant influence on the perception of /i/ epenthesis. Statistical analysis supports this, revealing no significant differences in perceived /i/ epenthesis rates between tense and lax vowels in either voicing condition. Specifically, the difference in the voiced condition is not significant ($p = 0.4940$), and the voiceless condition also shows no significant difference ($p = 0.4047$).

4.3.2.4.4 Listening score and vowel tenseness

The listening scores from two lax/tense discrimination tests and the tenseness of the pre-final vowel did not have a significant impact on the perception of /i/ epenthesis (listening score: $p = 0.3655$; tenseness: $p = 0.2650$), as shown in Table 4.17. Furthermore, the interaction between these factors did not yield a significant result for the perception of /i/ epenthesis ($p = 0.1433$). A subset of the results from Table 4.17 is reproduced in Table 4.21.

Table 4.21 Interaction of tenseness of the pre-final vowel and listening scores for perceived /i/ epenthesis

	Estimate	Std. Error	z value	Pr (>|z|)
(Intercept)	1.2891	0.1449	8.8922	<0.0001 ***
Tenseness Tense	0.1307	0.1173	1.1136	0.2650
Listening Score	0.0019	0.0021	0.9048	0.3655
Tenseness Tense:Listening Score	0.0104	0.0071	1.4630	0.1433

Given the lack of the significant interaction between these two factors, there is no evidence to support the argument that an increase in listening scores is related to a higher likelihood of perceiving /i/ epenthesis when the pre-final vowel is tense. In other words, native Korean listeners with higher listening scores do not exhibit a greater tendency to perceive epenthetic /i/ when the pre-final vowel is tense.

4.4 Conclusions

Chapter 4 examined the linguistic factors that shape native Korean listeners' perception of /ɨ/ and /i/ epenthesis. Specifically, the study investigated /ɨ/ epenthesis by analyzing the voicing, release, and place of articulation of the final consonant, in addition to the tenseness of the pre-final vowel. For /i/ epenthesis, it examined the voicing and noise duration of the final consonant, as well as the tenseness of the pre-final vowel. The results showed that the perceived /ɨ/ epenthesis rates increased when the final consonant was voiced, released, and either alveolar or velar. Similarly, the perceived /i/ epenthesis rates increased when the final consonant was voiced and had a long noise duration. Additionally, interactions between these factors influenced the perceived rates of both /ɨ/ epenthesis and /i/ epenthesis.

The study also examined whether native Korean listeners with greater ability to discriminate English tense and lax vowels perceive epenthesis more frequently in pre-final tense vowel contexts. The findings indicated a positive relationship between the tenseness of the pre-final vowel and the ability to distinguish English tense and lax vowels in /ɨ/ epenthesis; greater proficiency in this distinction was associated with a higher perceived rate of /ɨ/ epenthesis when the pre-final vowel was tense. A detailed discussion of all results will be provided in Chapter 5.

CHAPTER 5

DISCUSSIONS

5.1 Introduction

In Chapter 3, the first production experiment was conducted to investigate whether epenthetic /ɨ/ and lexical /ɨ/ produced by Korean monolingual speakers share the same phonetic features, and the second experiment explored the phonetic features of epenthetic and lexical vowels at different speech rates. Chapter 4 examined the linguistic factors that influence native Korean listeners' perception of epenthetic vowels.

Chapter 5 discusses the findings from Chapters 3 and 4. First, the same phonetic features of epenthetic /ɨ/ and lexical /ɨ/ produced by Korean monolinguals are examined in comparison to my previous study (2022) which found a difference in F2 between them. Next, the phonetic features of epenthetic and lexical vowels at normal and fast speech rates are discussed, along with the effects of different speech rates. Finally, this chapter discusses how linguistic factors and their interactions affect the perception of epenthetic vowels in Korean.

5.2 Production of vowel epenthesis

5.2.1 Vowel production in passage-level read speech

The study on passage-level read speech aimed to examine whether epenthetic /ɨ/ and lexical /ɨ/ in passage-level read speech differ from each other. In my previous research (2022), epenthetic /ɨ/ and lexical /ɨ/ in the Korean Broadcast News Speech corpus (Strassel et al. 2006) were analyzed and the findings revealed that (a) the durations of epenthetic and lexical /ɨ/ are identical, (b) both share the same F1 value, but (c) epenthetic /ɨ/ has a higher F2 compared to lexical /ɨ/. A potential explanation for this result is that the bilingualism of the Korean speakers in the corpus data. Korean-English bilinguals may reflect L2 English influence in their Korean speech. In English, the F1 formant value of [ɨ] (e.g., *roses* [ɹoʊzɨz]) is approximately 400 Hz, comparable to Korean lexical /ɨ/, but its F2 formant value ranges from 1900 to 2000 Hz (Flemming & Johnson 2007) significantly higher than the mean F2 value of Korean lexical /ɨ/ at 1500 Hz. Thus, the influence of English on the pronunciation of English loanwords may lead to the fronting of epenthetic /ɨ/ in the speech of Korean-English bilinguals. To determine whether the observed F2 differences between epenthetic /ɨ/ and lexical /ɨ/ result from English influence, this study analyzed passage-level read speech produced by Korean monolinguals. The results showed that epenthetic and lexical /ɨ/ produced by Korean monolinguals did not differ from each other. That is, epenthetic /ɨ/ in my previous study (2022) may have been affected by bilingualism. According to Kadenge and Mudzingwa (2012), chiShona monolinguals and chiShona-English bilinguals may apply distinct phonological rules when adapting English loanwords in chiShona. One key difference between English and chiShona lies in their syllable structures. ChiShona prohibits any consonant clusters in onset positions, so vowel epenthesis is required to break up these clusters in English loanwords in chiShona. However, chiShona-English bilinguals tend not to use vowel epenthesis and produce consonant clusters in English loanwords. In addition, /l/ is absent from the chiShona consonant inventory, so it is substituted with /r/ during the process of loanword adaptation in chiShona. However, chiShona-English bilinguals use /l/ instead of /r/ in English loanwords. Thus, Kadenge and Mudzingwa (2012) argue that chiShona-English bilinguals may apply English phonology to English loanwords in chiShona. Zellou (2011) also observed that Moroccan Arabic-French bilingual speakers produce /u/ differently in native Moroccan Arabic words and French loanwords. Specifically, bilingual speakers use /ɔ/ which sounds more similar to French, while Moroccan Arabic monolinguals use /u/ in French loanwords. Zellou (2011) argues that French may influence bilingual speakers to produce sounds in French loanwords that differ from those in Moroccan Arabic.

My previous study (2022) examined the production of epenthetic /ɨ/ and lexical /ɨ/ by Korean-English bilinguals, while the current study focuses on Korean monolinguals. The results from the previous study show that Korean-English bilinguals produced a higher F2 for epenthetic /ɨ/ in English loanwords, making it more similar to English [ɨ]. On the other hand, the present study found that Korean monolinguals produced the same /ɨ/ in both English loanwords and Korean lexical words. Given that English central [ɨ] typically has a higher F2 than Korean back /ɨ/, Korean-English bilinguals may incorporate English [ɨ] into English loanwords in their Korean speech. As a result, epenthetic /ɨ/ exhibits a higher F2 than lexical /ɨ/.

According to LaCharité and Paradis (2005), when producing loanwords, bilinguals strive to preserve the original form of the word from the source language while also modifying it to align with the phonological system of the recipient language. As a result, the pronunciation of loanwords by bilinguals often reflects both requirements, leading to phonetic features that may distinguish loanwords from native words in the recipient language. This explanation can apply to Korean-English bilinguals. They may attempt to satisfy these requirements by using the original English vowel [ɨ] in the epenthetic vowel position to align with Korean phonological rules.

5.2.2 Vowel production at different speech rates

The goal of the study was to investigate the phonetic differences between epenthetic and lexical vowels at normal and fast speech rates and to compare the phonetic characteristics of these vowels across the two speech rates.

First, the results showed that the F1 and F2 formant values of epenthetic /ɨ/ and lexical /ɨ/ at the normal speech rate were similar, and those at the fast speech rate were also similar to each other. In addition, both epenthetic /ɨ/ and lexical /ɨ/ at the normal speech rate showed a similar coarticulation effect on their formant values: (a) the F1 formant values of both epenthetic /ɨ/ and lexical /ɨ/ did not vary depending on the place of articulation of the preceding consonant, but (b) their F2 formant values were significantly affected by it. Specifically, F2 increased when epenthetic /ɨ/ and lexical /ɨ/ followed an alveolar consonant and decreased when they followed a bilabial consonant. It is well known that the F2 formant values of vowels vary depending on the place of articulation of the preceding consonant (Cooper et al. 1952; Kondo 1994; Koopmans-van Beinum 1994), and coarticulation may contribute to this F2 variation. According to previous studies (Cooper et al. 1952; Jachova et al. 2021; Kerdpol 2012; Kishon-Rabin et al. 2003; Liberman et al. 1954), labial consonants tend to have lower F2 values than coronal consonants, and this tendency may influence the F2 formant values of following vowels due to coarticulation. On the other hand, at the fast speech rate, the F2 formant values of epenthetic /ɨ/ and lexical /ɨ/ did not vary based on the place of articulation in this study. This result may be attributed to the F2 lowering of coronal and dorsal consonants at the fast speech rate. According to Agwuele et al. (2009), the F2 formant values of coronal and dorsal stops decreased more than those of labial stops as speech rate increased from normal to faster and fastest. This tendency may also apply to the results of the current study, which showed that F2 formant values at the fast speech rate did not vary depending on the place of articulation.

This study hypothesized that the F2 formant value of epenthetic /ɨ/ would be more centralized than that of lexical /ɨ/ at the fast speech rate, while their F1 values would remain similar due to the underspecified nature of the F2 value in epenthetic /ɨ/. However, the results indicated that the F2 formant values of epenthetic /ɨ/ and lexical /ɨ/ did not show significant differences. This finding suggests that epenthetic /ɨ/ in English loanwords is not a transitional or targetless sound characterized by more centralized formants. Instead, the data support the notion that epenthetic /ɨ/ is fully articulated and produced with the same phonetic quality as lexical /ɨ/ in Korean.

The durations of epenthetic /ɨ/ and lexical /ɨ/ were the same at each speech rate and showed similar patterns. First, at the normal speech rate, the durations of both epenthetic /ɨ/ and lexical /ɨ/ increased when (a) the vowel was in the final word position, (b) it was in the open syllable, and (c) it was produced by male speakers. Vowels in final positions are generally produced with a longer duration than those in non-final positions. For example, Umeda (1975) found that unstressed vowels in American

English are longer in word-final syllables than in other syllables. Additionally, van Santen (1992) argues that both stressed and unstressed vowels are longer in word-final syllables compared to non-word-final syllables in American English. Vowels in word-final syllables may be influenced by pre-pausal lengthening which indicates that vowel lengthening occurs before a pause (Duanmu 1996; Klatt 1976; O'Shaughnessy 1980). According to O'Shaughnessy (1980), the durations of both French consonants and vowels in the final syllables of words are longer than those in non-final syllables, and he argues that a pause immediately following the final syllable may cause this vowel lengthening. This pre-pausal lengthening may affect Korean vowels in the final syllables of words in this study. Conversely, pre-pausal lengthening effect on epenthetic /ɨ/ and lexical /ɨ/ vanished at the faster speech rate due to fast speech rate compression diminishing pre-pausal lengthening. Albano (1999) observed that in Brazilian Portuguese, pre-pausal lengthening disappears at the fast speech rate; thus, vowels in final-word positions had similar durations to those in non-final positions. Albano (1999) explains that the compression associated with fast speech reduces the length of pre-pausal vowels to approximately match that of other vowels in non-final positions.

Next, in many languages including Korean, vowels in open syllables are generally pronounced longer than those in closed syllables (Choi & Jun 1998; Curtis 2002; Oh 2016; Rositzke 1939). For instance, Oh (2016) studied V, CV, VC, and CVC syllable types and found that vowels were longest in V syllables, followed by CV, then VC, and shortest in CVC syllables in Korean. In addition, Rositzke (1939) shows that both monophthongs and diphthongs in open syllables have longer vowel durations than those in closed syllables in General American English. Previous studies (Fowler 1981; Klatt 1976; Lindblom & Rapp 1973) argue that this phenomenon may be relevant to compensatory shortening. Vowels tend to shorten in length compared to other intrasyllabic segments without losing their phonetic features. Thus, vowels become shorter when the syllable coda contains more consonants to compensate for the added length of the coda as a means of allowing speakers to maintain a constant syllable duration.

In contrast, the compensatory shortening of epenthetic /ɨ/ and lexical /ɨ/ disappeared at the fast speech rate in this study. In many languages, speech rate can change temporal patterns (Smith 2000, 2002). According to Smith (2002), these temporal patterns can result from two different effects: prosodic and phonetic. The prosodic effect is influenced by a segment's position within an utterance, affecting the temporal patterns such as utterance-final lengthening. On the other hand, the phonetic effect is related to adjacent segments such as vowel lengthening before voiced stops. Smith (2002) argues that temporal patterns caused by prosodic effects tend to remain stable across different speech rates, whereas those caused by phonetic effects vary with changes in speech rate. For example, vowel lengthening before voiced stops decreased as speech rate increased, with segments becoming shorter compared to the normal speech rate. In contrast, utterance final-syllable vowel lengthening did not show this tendency at the fast speech rate. The results may suggest that temporal patterns caused by prosodic effects are more resistant to changes depending on speech rates, as speakers have learned these patterns as a speech production pattern and perceptual cue (de Jong & Zawaydeh 1999; Smith 2002). In this study, vowel durations are shorter in closed (CVC) syllables than in open (CV) syllables, and this compensatory vowel shortening is more likely to be a temporal pattern influenced by the adjacent segment rather than by the overall vowel position in the utterance. Thus, the vowel duration difference between closed and open syllable structures can diminish due to the compression caused by the faster speech rate.

Gender also affects the duration of epenthetic /ɨ/ and lexical /ɨ/ at both speech rates. Male speakers pronounced vowels shorter than female speakers in many languages (Holt et al. 2015; Lee & Jin 2016; Simpson & Ericsdotter 1998). For example, Lee and Jin (2016) argue that Korean male speakers pronounce both monophthongs and diphthongs more quickly than Korean female speakers. Also, Holt et al. (2015) found that vowel durations of male speakers are shorter than those of female speakers in both African American English and White American English. Simpson and Ericsdotter (1998) suggest that durational differences between genders may result from the physical difference in male and female vocal tracts. Specifically, biomechanical distinctions in vocal tract structures between genders can result in differing articulatory distances needed to reach the same phonetic targets. Due to their larger vocal tracts, male speakers may move their articulators over greater distances. To compensate, they increase their articulatory speed, allowing them to reach the same phonetic targets more quickly. As a result, male speakers generally speak at a faster pace and produce shorter vowel durations.

Next, the results for epenthetic /i/ and lexical /i/ showed that (a) their F1 and F2 formant values and durations did not differ at the normal speech rate, and (b) they remained the same at the fast speech rate. Unlike /ɨ/ epenthesis, /i/ epenthesis occurs only in specific environments: it appears in an open word-final syllable, and the preceding consonant is always an English post-alveolar. Thus, differences in F2 formant values based on the place of articulation of the preceding consonant, and differences in duration related to syllable position (final vs. non-final) and structure (closed vs. open) were not relevant in this study. In terms of gender, male Korean speakers produced longer durations for both epenthetic /ɨ/ and lexical /i/ compared to female Korean speakers at both speech rates. Hence, epenthetic /i/ and lexical /i/ exhibited similar phonetic features in Korean.

This study hypothesized that both epenthetic and lexical vowels would undergo vowel centralization and reduced vowel durations at the fast speech rate. However, the results showed that while epenthetic and lexical /i/ exhibited both vowel centralization and shorter durations, epenthetic and lexical /ɨ/ only underwent vowel shortening during fast speech. The hypothesis for centralization and vowel shortening was based on undershoot which commonly occurs at faster speech rates. The articulation of reduced vowels tends to become similar to the schwa /ə/ (Moon & Lindblom 1994; Stetson 1951), a process known as 'undershoot' which refers to phonetic vowel reduction. Undershoot may cause the vowel space to become centralized as vowel duration shortens (Guenther 1995; Koopmans-van Beinum 1980; Lindblom 1963). It is known that undershoot occurs in unstressed or weakly stressed vowels due to their shorter durations in stress-timed languages. That is, these vowels may be produced with a shorter duration than their corresponding stressed vowels, and their short durations may cause undershoot (Lindblom 1963). However, undershoot is not a phonetic characteristic exclusive to stress-timed languages, as vowel durations are also influenced by other linguistic factors. One factor affecting vowel durations is speech rate, and it can cause undershoot (Fourakis 1991; Jaworski 2009; Miller 1981; Nadeu 2014; Padgett et al. 2005). In fast speech, the time available for pronouncing vowels decreases compared to slow and normal speech, so there is not enough time to reach the target vowel articulation. As a result, vowel formants become centralized when vowel duration shortens during fast speech. For example, Nadeu (2014) argues that in Catalan, a faster speech rate affects undershoot even more than the absence of stress, as it reduces vowel duration more than the absence of stress does.

In Korean, undershoot can happen due to the fast speech rate (Igeta et al. 2017; Son 2017). Son (2017) compared the vowel formants of /ɑ, i, u, æ, ɛ, o, ʌ, ɨ/ at normal and fast speech rates. The results confirmed that (a) F1 for /ɑ/ decreased, (b) F2 for /i/ and /ɛ/ decreased, and (c) F2 for /u/ and /o/ increased at the fast speech. Even though not all Korean vowels showed undershoot, some were still centralized at the fast speech rate. The results of the current study are, to some extent, consistent with Son (2017). In this study, both epenthetic /i/ and lexical /i/ showed increased F1, decreased F2, and shortened duration at the fast speech rate. This suggests that these vowels were centralized due to undershoot. Although Son (2017) argues that the F1 of lexical /i/ does not change at the fast speech rate in Korean, F1 changes frequently during fast speech due to undershoot, even in non-stress-timed languages. For example, the F1 formant values of Japanese /o/ and /e/ became centralized at fast speech rates (Hirata & Tsukada 2003). Also, Spanish /i, e, a, o, u/ showed centralized F1 during fast speech (Jaworski 2009).

On the other hand, in this study, the F1 and F2 formants values for both epenthetic /ɨ/ and lexical /ɨ/ remained unchanged at the fast speech rate, even though their durations shortened at the fast speech rate. According to Jaworski (2009), not all vowels are subject to undershoot in the same manner. Jaworski (2009) investigated Polish, Spanish, and Russian and found that high vowels /i, u/ were more susceptible to undershoot than others during fast speech and central vowels /a, ɨ/ were least influenced by undershoot. Jaworski (2009) explains this result by vocal tract inertia. Articulators tend to maintain their current motion or position during speech, and this is known as vocal tract inertia. Because of this inertia, articulators cannot fully achieve the target articulation, especially during fast speech. This is called inertial lenition, and one of the processes involved in inertial lenition is undershoot. Jaworski (2009) argues that since vocal tract inertia applies to all speech production, inertial lenition is a universal feature and suggests a cross-linguistic hierarchy of susceptibility to inertia for vowels: high vowels /i, u/ > mid vowels /e, o/ > central vowels /a, ɨ/ (Jaworski 2009:126). High vowels /i/ and /u/ are the most peripheral in the vowel space, and these extreme positions are more challenging to maintain for full articulation against inertia in fast speech. As a result, undershoot occurs more frequently with these vowels. On the other hand, central vowels may require the least articulatory effort since they are already located near the center of the vowel space. Thus, they are least affected by inertia and do not undergo as much undershoot as high vowels. Jaworski (2009)'s hierarchy of susceptibility to inertia can account for the results of the current study, where both epenthetic /i/ and lexical /i/ underwent undershoot, while epenthetic /ɨ/ and lexical /ɨ/ did not. In the Korean vowel inventory, /i/ is the most peripheral vowel, making both epenthetic /i/ and lexical /i/ more susceptible to undershoot in fast speech due to vocal tract inertia. In contrast, the Korean central vowel /ɨ/ with slight tongue retraction was less affected by inertia than the high vowel /i/.

5.2.3 Conclusions

In Chapter 3, studies were conducted to investigate the F1 and F2 formant values and durations of epenthetic /ɨ/ and lexical /ɨ/ in passage-level read speech and to examine those of epenthetic and lexical vowels at different speech rates.

First, this study analyzed passage-level speech from Korean monolinguals to examine whether epenthetic /ɨ/ and lexical /ɨ/ have the different phonetic characteristics since my previous study (2022) found that epenthetic /ɨ/ had a higher F2 compared to lexical /ɨ/ produced by Korean-English bilinguals.

In the study, the result showed no significant differences in phonetic characteristics between epenthetic /ɨ/ and lexical /ɨ/ in Korean monolingual speakers' speech, and it suggests that the F2 differences observed previously may indeed reflect the F2 formant value of English [ɨ]. Earlier studies (Kadenge & Mudzingwa 2012; LaCharité & Paradis 2005; Zellou 2011) demonstrated that bilinguals may apply the phonology of one language when producing loanwords from the other. Thus, speakers in my previous study (2022) may use English [ɨ] in English loanwords in their Korean speech.

The F1 and F2 formant values and durations of epenthetic and lexical vowels showed no differences at normal and fast speech rates. Also, while epenthetic /i/ and lexical /i/ were centralized to a similar extent at the fast speech rate, neither epenthetic /ɨ/ nor lexical /ɨ/ showed centralization. These findings also indicate that epenthetic and lexical vowels in Korean behave identically across different speech rates.

In this study, experimental results show that epenthetic vowels have F1 and F2 formant values and durations similar to those of lexical vowels. This suggests that epenthetic vowels are used as full segments with phonetic targets, rather than emerging from articulatory transitions like a transitional schwa (Davidson 2006; Davidson & Stone 2003). Thus, in Korean, epenthetic vowels are fully integrated into the phonological system and behave like lexical vowels.

5.3 Perception of vowel epenthesis

This study investigated the linguistic factors affecting the likelihood of perceiving /ɨ/ and /i/ epenthesis in English loanword adaptation in Korean based on ABX perceptual experiments. The following hypotheses were made to examine how the release, voicing, and place of articulation of the final consonant, and the tenseness of the pre-final vowel affect the perception of vowel epenthesis.

(5.1) More perceived epenthesis occurs when:

- The final consonant is released for /ɨ/ epenthesis.
- The final consonant is either alveolar or velar for /ɨ/ epenthesis.

- The final consonant has a longer noise duration for /i/ epenthesis.
- The final consonant is voiced for both types of epenthesis.
- The pre-final vowel is tense, especially when native Korean listeners can distinguish between English tense and lax vowels for both types of epenthesis.

This chapter discusses the perceptual results of each hypothesis and the interactions between these factors. By doing so, this study may help identify epenthetic patterns in English loanword phonology and illustrate the intricate interactions between linguistic factors that influence phonological outcomes in English loanword adaptations.

5.3.1 Release of the final consonant

The release of the final consonant significantly affects the native Korean listeners' perception of /ɨ/ epenthesis in this study. When the final consonant is released, the perceived /ɨ/ epenthesis rate become higher. In other words, native Korean listeners perceive the final released consonant as more likely to end in an epenthetic vowel. This result is consistent with perceptual studies on the effect of the release of the final consonant (Chung 1986; Kim 2008; Kim 2021). The release bursts of foreign consonants can be misperceived as epenthetic vowels by non-native listeners because release bursts and vowels share similar acoustic features (Byrd 1993; Goad & Kang 2003; Kim 2021; Kim-Renaud 1977; Parker 1977; Silverman 1996; Wilson et al. 2014). Specifically, the acoustic energy from the release bursts of consonants, especially obstruents, may be perceived by non-native listeners as the nucleus of an extra syllable. This acoustic feature can lead non-native listeners to incorrectly interpret the consonant release as a vowel resulting in vowel epenthesis. Furthermore, the fact that release bursts are not permitted in coda positions in Korean may lead native Korean listeners to be even more likely to perceive an epenthetic vowel when they encounter released final consonants in English. Specifically, in Korean, a final stop is acoustically produced with silence and without any oral burst, which means that a final stop is not released at all (de Jong & Park 2012; Kim 1998). Therefore, if an English released consonant is used as a Korean coda in

English loanword adaptations, it must lose its release. On the other hand, an onset consonant can be released right before a vowel in Korean. If vowel epenthesis occurs, an English released coda becomes a Korean onset, and it can keep being released in Korean. Thus, native Korean listeners expect that a vowel may follow an English released coda.

5.3.2 Noise duration of the final consonant

The final consonant had a longer noise duration, and native Korean listeners perceived epenthetic /i/ more often than when it had a shorter noise duration in this study. According to de Jong and Park (2012), sibilant codas introduce more perceived /ɨ/ epenthetic vowels than non-sibilant codas in VC structures. This suggests that native Korean listeners perceive VC sequences ending in sibilants as more similar to /VCɨ/ than those ending in non-sibilants. de Jong and Park (2012) argue that this result can be attributed to Korean listeners misperceiving the salient noise of sibilants as an epenthetic vowel. Thus, it is possible that when a sibilant has a long duration, it may lead to a higher probability of perceived epenthesis. This assumption is confirmed by the results of this dissertation. Therefore, a long noise duration serves as a critical phonetic cue for the perception of /i/ epenthesis in Korean.

5.3.3 Place of the final consonant

In this study, the place of articulation of the final stop significantly affects the perception of /ɨ/ epenthesis. The results show that /ɨ/ epenthesis is perceived more frequently when the final stop is either alveolar or velar than when it is bilabial. This result is supported by other studies (de Jong & Park 2012; Kim 2018; Kwon 2017) which argue that the place of articulation itself affects native Korean listeners' perception of /ɨ/ epenthesis. According to Kwon (2017), both alveolar and velar final stops lead to /ɨ/ epenthesis more often than a bilabial one in the released and unreleased conditions and there were no differences between alveolar and velar final stops. In other words, the place of articulation itself may influence the likelihood of perceiving /ɨ/ epenthesis.

On the other hand, some studies argue (Kang 2003; Wilson et al. 2014) that the place of articulation itself does not have any effect on /ɨ/ epenthesis in English loanword adaptations. For instance, Kang (2003) claims that the higher probability of /ɨ/ epenthesis following coronal stops is due to their relatively longer and stronger release bursts compared to labial stops. It is a well-known fact that coronal and dorsal consonants have stronger release bursts (Repp 1984; Wilson et al. 2014) and these strong release bursts of the final stop may lead to more perceived /ɨ/ epenthesis. Thus, if the release burst is eliminated, the place of articulation should no longer influence the perceived rate of /ɨ/ epenthesis. However, the current study showed that the place of articulation still affects the perception of /ɨ/ epenthesis even when the final stop is unreleased.

According to Kwon (2017), native Korean listeners have already learned that English coronal and dorsal final stops are more often adapted with epenthetic /ɨ/ into Korean compared to English labial codas, and they may apply this rule when encountering new English words. Also, Walter (2006) argues that native speakers possess an understanding of the distributional patterns and knowledge in their native lexicon and may apply this understanding when they borrow new foreign words to preserve the established distributional patterns and knowledge in their native lexicon. In addition, according to Bybee (2001), the frequency of certain sounds, morphemes, or words appearing together influences speakers' phonological patterns, and repeated exposure to these patterns shapes phonological structure, as language users store and generalize distributional patterns. Along these lines, native Korean listeners may have distributional knowledge of both the English loanword lexicon and the native Korean lexicon. They already experience and recognize that coronal and dorsal stops are more likely to be borrowed with /ɨ/ epenthesis as a distributional pattern. As a result, they may apply this pattern when encountering new English nonce words in this study.

Another possible explanation for the observed differences in the effect of the place of articulation on /ɨ/ epenthesis may relate to the fact that the closure duration of final stops is longer at the end of an utterance than in other positions across typologically different languages (Bell-Berti et al. 1991; Berkovits 1993, 1994). For example, Berkovits (1993, 1994) found that the closure durations of English final voiced and voiceless stops, as well as Hebrew final voiceless stops, are significantly longer in utterance-final positions compared to other positions within an utterance. Additionally, Bell-Berti et al. (1991) conducted a comparative study of French final voiceless stops produced by normal French speakers and French-speaking ataxic dysarthric speakers. The results of the study indicated that French final voiceless stops in normal speech have a notably longer closure duration at the end of the utterance, whereas French-speaking ataxic dysarthric speakers did not exhibit any increase in closure duration for final stops. Based on these studies showing a universal tendency for stops to be marked by increased closure duration at the end of an utterance, it can be inferred that the long closure duration of consonants is a key perceptual cue for listeners to identify the end of an utterance. Cross-linguistically, labial stops exhibit longer closure durations compared to coronal and dorsal stops (Repp 1984; Stathopoulos & Weismer 1983). According to Stathopoulos and Weismer (1983), the closure durations of English bilabial stops are consistently longer than those of English alveolar and velar stops across various linguistic contexts including voicing, stress, and positional variations. As a result, the longer closure duration of English bilabial stops might provide clearer perceptual cues that signal the end of the utterance, thereby reducing the need for an epenthetic vowel. This perceptual clarity of bilabial stops may reduce confusion for native Korean listeners, whether epenthetic /ɨ/ is used or not. On the other hand, the shorter closure duration of English alveolar and velar stops may result in less distinct boundaries potentially leading native Korean listeners to use /ɨ/ epenthesis in English loanword adaptations.

5.3.4 Voicing of the final consonant

This study shows that the voicing of the final consonant greatly influences the likelihood of perceiving both /ɨ/ and /i/ epenthesis. Native Korean listeners are more prone to hearing an epenthetic vowel following a voiced consonant than a voiceless one.

Korean has only voiceless consonants as phonemes: plain voiceless consonants, aspirated voiceless consonants, and tense voiceless consonants. Among these, plain voiceless consonants become voiced when placed between two vowels. If vowel epenthesis occurs after a voiced consonant, perceptual similarities between an English input and a Korean output may be preserved (Boersma & Hamann 2009; Kang 2003; Kwon 2017). For example, if /ɨ/ epenthesis occurs in an English CVC monosyllabic word ending in a voiced stop, it is highly likely to become /CVCɨ/ in Korean. In /CVCɨ/, the second voiceless consonant becomes voiced and sounds like the English voiced consonant because it appears between two vowels. This ensures that perceptual similarities between the English voiced consonant and the Korean voiced consonant which was originally voiceless can be maintained.

5.3.5 Tenseness of the pre-final vowel and listening scores

Neither the tenseness of the pre-final vowel nor the listening scores has a significant effect on the perception of /ɨ/ or /i/ epenthesis in this study. The tenseness of the pre-final vowel has been widely discussed in the literature. Previous studies (Chung & Huckvale 2001; Kim 2021; Koo 1998; Kwon 2017) argue that /ɨ/ epenthesis is more common when the pre-final vowel is tense. This phenomenon is linked to vowel length variations in different Korean syllable structures. In many languages including Korean, vowels in open syllables are longer than those in closed syllables, and tense vowels are longer than lax vowels (Curtis 2002; Kwon 2017; Maddieson 1985). Consequently, when native Korean listeners hear a tense vowel in an English closed CVC syllable, they anticipate this tense vowel in an open syllable. As a result, native Korean listeners may use vowel epenthesis to change the English closed syllable into an open syllable (i.e., /CVCɨ/). On the other hand, Kim (2022) reports that the tenseness of the pre-final vowel does not affect vowel epenthesis. This discrepancy raises questions about why vowel tenseness has led to varying perceptual results in studies, while other phonological factors such as release and voicing yield consistent results.

One possible explanation for these results is that perceptual studies on vowel tenseness must assume that native Korean listeners can accurately perceive the English tense and lax contrast. Earlier perceptual studies (Kahng 2006; Kim 2012) tested whether native Korean listeners could distinguish between English tense and lax vowels. The results indicate that individuals often struggle to distinguish between English tense and lax vowels due to the absence of tense and lax vowel distinctions in Korean. Despite this, many previous perceptual studies have not focused much on the ability of native Korean listeners to distinguish between English tense and lax vowels.

This dissertation examined native Korean listeners with varying abilities to distinguish between tense and lax vowels. The results showed that this ability did not independently influence the perceived rates of /ɨ/ and /i/ epenthesis. However, there was a significant relationship between this ability and the perception of /ɨ/ epenthesis when the vowel was tense. This result is discussed in detail in §5.3.10.

5.3.6 Interaction between release and voicing of the final consonant

In this study, the voicing of the final consonant loses its impact on perceived /ɨ/ epenthesis rates when the final consonant is released. However, when the final consonant is unreleased, English nonce words ending in a voiced consonant are more likely to be perceived as having an epenthetic vowel than those ending in a voiceless one. According to Kwon (2017), native Korean listeners may focus on the release of the final consonant rather than its voicing if the final consonant is released, whereas they may focus on the voicing of the final consonant if it is not released. This explanation is based on the argument that listeners may focus more on the release of the consonant than on its voicing, supported by other studies (Halle et al. 1957; Kim 2021; Shinohara 2006; Zue 1976). Cross-linguistically, voiceless stops have a longer release duration compared to voiced ones due to the greater pressure behind the stop closure and the increased pressure in the production of voiceless stops (Halle et al. 1957; Kim 2021; Zue 1976). This tendency may cause phonological changes in loanword adaptation in many languages. For example, Shinohara (2006) examines the patterns of word-final deletion in English loanword adaptations in many different languages. The noticeable observed deletion pattern is the preference for voiceless stops over voiced ones in certain contexts such as the postnasal context (N___#) in many languages. This asymmetric deletion related to the voicing can be explained by the relative acoustic and auditory saliency of the voiceless stops. Voiceless stops are more salient than voiced stops in that voiceless ones have longer release. As a result, the explanation that native Korean speakers may care more about the release can be supported by the argument that voiceless stops are more likely to be retained than voiced ones in loanword adaptation across many different languages due to their release saliency. Native Korean listeners who focus on the release of the final stop rather than its voicing may perceive the longer release of voiceless stops as the epenthetic vowel in that only Korean onset consonant can be released right before a vowel. This may result in a perceived epenthesis rate similar to that after voiced stops in the released condition. Indeed, the release durations of voiceless stops are longer than the release durations of voiced stops in this study.

Table 5.1 Mean stop release duration (ms)

	Mean release duration (SD)
Voiceless stop	21.19 (13.59)
Voiced stop	15.40 (9.92)

As shown in Table 5.1, the release durations of voiceless stops significantly longer than the release durations of voiced stops ($p < 0.0001$). Hence, native Korean listeners who focused on the release of the final stop rather than its voicing might perceive the longer release of voiceless stops as an epenthetic vowel, resulting in a perceived epenthesis rate similar to that found after voiced stops in the released condition.

5.3.7 Interaction between noise duration and voicing of the final consonant

Interestingly, the noise duration of the final consonant in /i/ epenthesis had a similar effect to the release of the final consonant in /ɨ/ epenthesis. If the final consonant had a long noise duration, its voicing did not influence the perceived /i/ epenthesis rates. On the other hand, when the final consonant had a short noise duration, voicing did affect the perception of /i/ epenthesis. Specifically, voiced consonants led to higher rates of perceived epenthesis than voiceless ones.

Like the release, this result can also be explained by a perceptual focus shift among native Korean listeners. Their perceptual focus is on the noise duration of the final consonant when it is long. On the other hand, if the noise duration is short, the focus shifts to its voicing. According to Jongman et al. (2000), sibilants have higher spectral peaks and amplitude than non-sibilants. However, while non-sibilants show spectral peak differences between their voiced and voiceless counterparts, no significant difference is found between voiceless and voiced sibilants. Thus, voiced and voiceless sibilant pairs tend to be perceptually similar. When the noise duration is long, native Korean listeners may focus more on it, as it is perceptually more salient than the voicing of the final consonant. However, when the noise duration is short, they tend to focus on voicing instead. Generally, the noise durations of voiceless affricates are longer than those of voiced ones (Cole & Cooper 1975), and the same result was found in this study.

Table 5.2 Mean noise duration (ms)

	Mean noise duration (SD)	
	Short	Long
Voiceless affricate	165.09 (7.38)	249.31 (12.73)
Voiced affricate	102.15 (8.02)	173.84 (10.65)

In Table 5.2, the overall noise duration of voiceless affricates is longer than that of voiced affricates (p = 0.0012). Hence, native Korean listeners focusing on the noise duration of the final consonant may perceive the longer noise duration of voiceless consonants as an epenthetic vowel, and this may have resulted in a perceived epenthesis rate similar to that found after voiced consonants in the long noise duration condition.

5.3.8 Interaction between release and place of articulation of the final consonant

The results of this study show that in both released and unreleased conditions, alveolar and velar stops lead to a significantly higher frequency of perceived /ɨ/ epenthesis compared to bilabial stops, with no observed difference between alveolar and velar stops. Also, a final released consonant results in a higher perceived rate of /ɨ/ epenthesis compared to an unreleased final stop across all places of articulation. This phenomenon can be attributed to the fact that English release bursts may be misperceived as an epenthetic vowel by native Korean listeners, as release bursts and vowels share similar acoustic features. According to previous studies (Byrd 1993; Kim 2021; Wilson et al. 2014), as the duration of the release burst increases, non-native listeners are more likely to perceive it as a vowel. Coronal and dorsal stops generally have a longer release duration compared to labial stops (Repp 1984; Wilson et al. 2014); thus, it is expected that /ɨ/ epenthesis is perceived more often after alveolar and velar consonants. In this study, alveolar and velar stops had a longer release burst than bilabial stops, as shown in Tables 5.3 and 5.4 below.

Table 5.3 Mean release duration (ms)

Place of articulation	Mean release duration (SD)
Alveolar	19.33 (15.03)
Velar	21.97 (17.81)
Bilabial	11.15 (9.42)

Table 5.4 Tukey's pairwise comparisons for release durations

Contrast	Estimate	Std. Error	z value	Pr (>|z|)
Alveolar - Velar	−0.0192	0.1361	−0.1411	0.8878
Bilabial - Alveolar	−1.9655	0.1739	−11.3025	<0.0001 ***
Bilabial - Velar	−1.5827	0.2198	−7.1974	<0.0001 ***

As shown in Tables 5.3 and 5.4, velar stops have the longest release duration, bilabial stops have the shortest, and alveolar stops have an intermediate duration. Statistically, both alveolar and velar stops are significantly longer than bilabial stops (alveolar: $p < 0.0001$; velar: $p < 0.0001$), and no significant difference was found between them ($p = 0.8878$). These durational results align with findings from previous research on consonant release (Byrd 1993; Kim 2021; Repp 1984; Wilson et al. 2014). Therefore, native Korean listeners may be more likely to perceive the longer release duration of alveolar and velar stops as the epenthetic /ɨ/ compared to the shorter release duration of bilabial stops.

5.3.9 Interaction between place of articulation and voicing of the final consonant

Regardless of whether the final stop is voiced or voiceless, alveolar and velar stops consistently result in more perceived /ɨ/ epenthesis compared to bilabial stops in this study. Furthermore, there is an interaction between voicing and bilabial stops: while perceived /ɨ/ epenthesis occurs more frequently when the final stop is a voiced alveolar or voiced velar compared to their voiceless counterparts, the difference between voiced and voiceless conditions is not significant for bilabial stops. According to de Jong and Park (2012), native Korean listeners may perceptually identify English voiced and voiceless stops more accurately in CV syllable structures than in VC ones. This might be related to voice onset time (VOT) and fundamental frequency (F0) transition for the identification of English voicing. Generally, native Korean speakers use both VOT and F0 to distinguish English voiced and voiceless stops in perception and production (Kim 2012; Son 2017; Sung et al. 2020). They tend to perceive English stops with longer VOT and higher F0 as voiceless. This use of both cues helps them distinguish English voiceless and voiced stops more easily and accurately in CV forms. In the transition from a consonant to a vowel in CV forms, VOT and F0 cues are more obvious and easier to discern, making the distinction between voiced and voiceless stops clearer. In contrast, the transition from a vowel to a consonant in VC forms can obscure VOT and F0 cues, making it more difficult for native Korean listeners to accurately perceive the voicing of the final stop. Perceptual difficulties in distinguishing voicing are particularly evident with labial consonants. de Jong and Park (2012) argue that labial consonants exhibit relatively lower accuracy in voicing distinctions compared to other consonants in VC syllable structures. In the current study, all stimuli were presented in CVC syllable structures with varying linguistic factors in the coda position, so it is possible that some native Korean participants struggled to distinguish between the

English voiced bilabial /b/ and voiceless bilabial /p/. As a result, the voiced and voiceless conditions may not exhibit a significant difference for final bilabial stops. The perceptual challenges associated with VOT and F0 cues in VC forms, along with the inherent difficulty in distinguishing the voicing of labial stops may contribute to the lack of a significant distinction between voiced and voiceless final bilabial stops in perceived /ɨ/ epenthesis in this study.

5.3.10 Interaction between tenseness of the pre-final vowel and listening score

In this study, neither the listening scores from the two lax and tense discrimination tests nor the tenseness of the pre-final vowel had a significant effect on the perceived epenthesis rates of both /ɨ/ and /i/. However, the interaction of these two factors impacted the perceived /ɨ/ epenthesis rates. Specifically, native Korean listeners with higher proficiency in distinguishing English tense and lax vowels were found to perceive more /ɨ/ epenthesis in the pre-final tense vowel context. This suggests that the ability to distinguish these English vowel qualities may influence the perception of /ɨ/ epenthesis. Previous studies (Best & Tyler 2007; Chang 2013; Smith 2006; Wang 2023) claim that speakers' perceptual abilities in a source language can affect adaptation patterns in loanwords. For example, Wang (2023) argues that how native Mandarin speakers adapt English nonce words ending in a low vowel and nasal coda sequence depends on their English proficiency. Monolingual native Mandarin speakers and those with lower English proficiency focused on vowel backness, whereas speakers with higher English proficiency concentrated on the place of the nasal coda. Mandarin speakers with higher English proficiency can distinguish nasal coda contrasts in English and accurately perceive their acoustic details. As a result, they incorporate the nasal coda in their adaptations instead of relying on low vowels. Conversely, monolingual native Mandarin speakers and those with lower English proficiency rely on vowel backness, as it is a more predictable feature in Mandarin and is acoustically more prominent and sonorous than nasal codas. This leads to the same English word being adapted into two different forms in Mandarin. In addition, Best and Tyler (2007) propose that proficient L2 learners' perception differs from that of functional monolinguals and less proficient learners, as proficient L2 learners not only differentiate acoustic details but also identify abstract and useful phonological information. Best and Tyler (2007) explain that both proficient and non-proficient learners can easily map non-native sounds to their native phonemes when their native language and the target language share phonetic segments. The discrimination between two contrasting non-native sounds also becomes clearer when these sounds also exist in the learner's native language. On the other hand, if both non-native sounds are assimilated into the same phonological category in the native language, the discrimination between these sounds becomes less clear to non-proficient learners. In the case of Korean, since there is no tense/lax contrast and both English tense /i/ and lax /ɪ/ are assimilated into the Korean phoneme /i/, perceptual confusion may occur among Korean monolinguals and learners with lower English proficiency when hearing English forms with tense /i/ and lax /ɪ/. As a result, the interaction between the listening scores from the two lax/tense discrimination tests and the tenseness of the pre-final vowel may significantly affect the perception of vowel epenthesis. In this study, participants who accurately distinguished English tense and lax vowels detected the tenseness of the pre-final vowel and exhibited higher rates of perceived /ɨ/ epenthesis after pre-final tense vowels. These findings highlight the importance of considering different perceptual abilities in shaping phonological patterns in the loanword adaptation process. Also, this explanation could possibly account for the different outcomes regarding the tenseness of the pre-final vowel in previous studies. If vowel tenseness significantly impacts perceived /ɨ/ epenthesis rates, native Korean listeners may be able to correctly distinguish between English tense and lax vowels. Conversely, if vowel tenseness shows no significant effect, it possibly suggests that they may not clearly differentiate between the two. Therefore, the effect of vowel tenseness might depend on native Korean listeners' ability to perceptually distinguish between English tense and lax vowels.

In the case of /i/ epenthesis, the results showed that native Korean listeners with higher discrimination test scores did not exhibit an increased tendency to perceive /i/ epenthesis when the pre-final vowel was tense. A possible explanation for this result is perceptual familiarity with phonetic factors between English and Korean. According to Best (1995), if sounds in L2 exist in a listener's L1, these sounds are more perceptually salient to L1 listeners. This increased salience may make these sounds easier to recognize and process compared to sounds that do not exist in L1. Native Korean listeners are familiar with consonant voicing and release features because these also exist in Korean. This familiarity allows native Korean listeners to easily recognize and focus on these features perceptually when they encounter them in new English CVC forms. On the other hand, Korean does not distinguish between tense and lax vowels, so native Korean listeners generally lack familiarity with the English tense and lax contrast. In this study, when native Korean listeners heard English CVC forms, they might more easily focus on the familiar consonant voicing and release features. However, their perceptual attention to less familiar vowel tenseness may decrease. Consequently, instead of relying on the less salient perceptual cues for English tense and lax vowels, the robust phonological pattern in which /i/ epenthesis always occurs after an English post-alveolar consonant may influence the perception of /i/ epenthesis. According to Best and Tyler (2007), language experience constrains the perception of non-native speech sounds. Listeners' perception is shaped by their native language phonological system, leading to systematic biases when encountering non-native sounds. These biases cause listeners to either assimilate unfamiliar sounds to the closest category in their L1 or modify them in ways that align with native phonotactic rules. From the perspective of Best and Tyler (2007), the phonological pattern in which /i/ epenthesis consistently occurs after an English post-alveolar consonant may become part of Korean speakers' language experience. Over time, Korean speakers develop a perceptual bias that may lead them to expect epenthetic /i/ when hearing new English CVC words ending in an English post-alveolar. This tendency may be stronger when the perceptual cues influencing vowel epenthesis receive less attention from native Korean listeners.

5.3.11 Conclusions

The conventional explanation for vowel epenthesis in Korean claims that it arises from inherent syllable structure constraints. However, this approach falls short in addressing unnecessary epenthesis and the discrepancy between the strategies used in Korean lexical words and English loanwords to repair illicit inputs. Instead of relying solely on phonotactics, perceptual studies take a different approach by examining perceptual similarities between non-native inputs and native outputs to explore vowel epenthesis.

This chapter showed that both /ɨ/ and /i/ epenthesis in English loanword adaptations in Korean are perceptually influenced. However, vowel epenthesis in English loanwords may not be only caused by perception but rather by the result of an interaction among various factors. This study showed that perceptual misinterpretation plays a significant role, particularly in cases where the strong release and voicing of final consonant lead Korean listeners to misperceive them as an epenthetic vowel. In addition, the results also showed that the interaction of factors such as release, voicing, and place of articulation can serve as evidence of the phonetic effects on vowel epenthesis. For instance, this study found that when the final consonant is released, the voicing of the stop no longer affects the perceived /ɨ/ vowel epenthesis rate. This suggests that native Korean listeners' perceptual focus can shift depending on the phonetic environment and that vowel epenthesis arises from the interplay between phonetic and perceptual factors.

The influence of learned phonological patterns cannot be overlooked. The study highlights that even in the absence of perceptual cues such as unreleased final stops, alveolar and velar stops still lead to higher rates of perceived /ɨ/ epenthesis compared to bilabial stops. This suggests that native Korean listeners apply pre-existing phonological knowledge and distributional patterns learned from previous loanword adaptations. As a result, perceptual misinterpretation may often be supplemented by internalized phonological rules when adapting new English words in Korean. Moreover, native Korean listeners with higher proficiency in distinguishing English tense and lax vowels are more likely to perceive /ɨ/ epenthesis after tense vowels. This underscores the role of individual English ability in shaping phonological outcomes of English loanwords in Korean.

In conclusion, vowel epenthesis in English loanword adaptation reflects the interaction of perception, phonetic cues, phonological patterns, and language proficiency. While perception plays a key role, phonological rules also guide adaptation with phonetic characteristics and individual differences in English proficiency.

CHAPTER 6

CONCLUSIONS

Korean epenthetic vowels have been less explored compared to those in other languages. Thus, this dissertation aimed to investigate the following three main areas: (a) the phonetic characteristics of Korean epenthetic vowels in English loanword adaptation, comparing them with Korean lexical vowels in passage-level read speech, (b) the effect of speech rate on vowel quality, analyzing both epenthetic and lexical vowels at normal and fast speech rates in sentence-level read speech, and (c) the phonetic factors influencing native Korean listeners' perception of vowel epenthesis.

6.1 Production of vowel epenthesis

This dissertation found that epenthetic /ɨ/ and lexical /ɨ/ exhibit similar F1, F2, and duration values in passage-level read speech produced by Korean monolinguals. This result differs from my earlier study (2022) which showed that while the F1 formant values and durations of epenthetic /ɨ/ and lexical /ɨ/ are similar, epenthetic /ɨ/ has a higher F2 than lexical /ɨ/. A reasonable explanation for the higher F2 of epenthetic /ɨ/ could be the native-like English proficiency of the Korean speakers in the data[8], as bilinguals may incorporate L2 phonological patterns into loanwords in their L1 speech (Kadenge & Mudzingwa 2012; LaCharité & Paradis 2005; Zellou 2011). According to Flemming and Johnson (2007), the F2 formant value of English [ɨ] is higher than that of Korean /ɨ/, even though their F1 formant values are similar. Thus, unlike Korean monolinguals, Korean-English bilinguals may use English [ɨ] when pronouncing English loanwords in Korean, resulting in higher F2 formant values for epenthetic /ɨ/

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[8] Even though the data did not provide any language background for the speakers, the 'Korean Broadcast News Speech (Strassel et al. 2006)' was produced and aired in the Washington, D.C., area. Therefore, it can be assumed that the speakers have lived in the United States, are proficient in English, or are Korean-English bilinguals.

compared to lexical /ɨ/.

Since my previous study (2022) did not analyze the epenthetic /ɨ/ produced by each speaker individually, it is difficult to argue that every Korean-English bilingual in the data produce English [ɨ] in English loanwords. In addition, the lack of specific information about the speakers' language backgrounds made it difficult to determine whether this tendency applies to both early and late Korean-English bilinguals. Early and late bilinguals often behave differently in speech production (Amengual 2021; Bohn & Flege 1992; Francis et al. 2008; Mayr et al. 2024). Specifically, late bilinguals tend to be more influenced by L1 patterns in the production of L2 vowels, consonants, and suprasegmentals compared to early bilinguals. Furthermore, depending on whether their more dominant language is English or Korean, they might omit epenthetic vowels or retain them, and they might use English [ɨ] in English loanwords or not since the language dominance can take the important role in the bilinguals' speech production (Broselow 1984; Mohamed et al. 2019). Therefore, it would be valuable to study these unexplored areas with Korean-English bilinguals.

Next, this dissertation focuses on the phonetic characteristics of epenthetic and lexical vowels in Korean at different speech rates. The phonetic characteristics of epenthetic vowels and lexical vowels did not differ from each other at either normal or fast speech rates. Interestingly, even though their durations became shorter at the fast speech rate, epenthetic /ɨ/ and lexical /ɨ/ were not centralized during fast speech which may be attributed to vocal tract inertia. According to Jaworski (2009), vocal tract inertia refers to the resistance that articulators such as the tongue and lips encounter when performing rapid movements or accelerating quickly during speech production. This resistance can prevent the articulators from fully reaching their target positions and has a universal impact on speech production across languages. Jaworski (2009) argues that high vowels are more prone to undershoot during fast speech because their peripheral position in the vowel space, where vocal tract inertia has the greatest effect, makes them harder to fully articulate. In contrast, central vowels, located near the center of the vowel space, require less articulatory effort and are less affected by vocal tract inertia, resulting in significantly less undershoot compared to high vowels. The results of this study support Jaworski (2009)'s argument, as high /i/ showed clear centralization in the vowel space at the fast speech rate in Korean. Specifically, both epenthetic /i/ and lexical /i/ exhibited higher F1 and lower F2 formant values at the fast speech rate compared to the normal speech rate.

Also, this dissertation found that the fast speech rate may decrease both pre-pausal vowel lengthening and compensatory vowel shortening. At the normal speech rate, epenthetic /ɨ/ and lexical /ɨ/ were produced longer when used in an open syllable (compensatory vowel shortening) or in the word final position (pre-pausal vowel lengthening), but they disappeared at the fast speech rate. These results may be attributed to the effects of compression from the fast speech rate (Albano 1999; de Jong & Zawaydeh 1999; Smith 2002). In addition, gender affects the vowel durations. Specifically, the male speakers produce the shorter vowel duration than female speakers in both epenthetic and lexical vowels at both speech rates. This difference is quite common in many languages including English, Swedish, and Korean (Holt et al. 2015; Lee & Jin 2016; Simpson & Ericsdotter 1998). Male speakers typically have larger vocal tracts than female speakers, so they need to achieve higher articulatory speeds, resulting in faster speech rates compared to female speakers. Therefore, male speakers tend to produce shorter vowel durations.

This dissertation concludes that the phonetic characteristics of epenthetic and lexical vowels do not differ in Korean. In other words, Korean epenthetic vowels are full segments rather than transitional ones, as transitional vowels are articulatorily targetless and have shorter durations compared to full segments. For example, Finnish (Harms 1976) and Piro (Matteson & Pike 1958) have transitional epenthetic vowels. These epenthetic vowels vary across a wide central area, with the range of variation depending on surrounding linguistic contexts such as the preceding and following segments. In addition, these vowels are significantly shorter in duration compared to lexical vowels. Thus, Korean epenthetic vowels may be full segments rather than transitional epenthetic vowels.

Besides the fully integrated phonetic features of epenthetic vowels in Korean, English loanwords follow Korean morphological rules. For example, Korean has a liaison process, where if a vowel-initial suffix follows a consonant coda, the coda shifts to the onset of the following vowel (Jeong 2001; Wang et al. 2009). In the Korean word /nɑk/ 'pleasure,' the coda /k/ is realized as an onset when the objective suffix /-ɨl/ is attached. This rule also applies to English loanwords. In addition, if a Korean lexical word ends in a coronal coda, the coda is realized as [t]. For example, /tɑʧʰ/ 'anchor' is realized as [tɑt]. However, when a vowel-initial suffix follows this noun, the coronal coda can be realized as [s] in free variation. If the nominative suffix /-i/ follows, /tɑʧʰi/ can be pronounced as either [tɑʧʰi] or [tɑsi]. This free variation also occurs in English loanwords (Jun & Lee 2007; Kang 2003; Kwon 2017).

In some languages, loanwords behave differently from native words in morphological processes. For example, Japanese has stratification in its lexicon, where native words and loanwords belong to different strata: native vocabulary, Sino-Japanese vocabulary, foreign vocabulary, and onomatopoetic/mimetic vocabulary (Ito and Mester 2009, 2017). According to Ito and Mester (2017), morpheme structure constraints, morpheme combinatorics, and morphophonemic alternations serve as key criteria for categorizing lexical items into these strata. To explain the stratification, Ito and Mester (2017) propose a core-periphery structure. This structure ranges from the innermost lexical core, Lex^0 which includes only native words, to the most inclusive set, Lex^{max} which encompassing all lexical items. In this structure, loanwords fall into different strata, such as Lex^1 for established loanwords and Lex^2 for assimilated foreign words.

Some studies argue that, like Japanese, Korean also has three distinct strata in its lexicon: native vocabulary, Sino-Korean vocabulary, and recent foreign vocabulary (Sohn 1999). However, given that epenthetic vowels in English loanwords are fully integrated into Korean phonology and that English loanwords conform to major morphological rules, the boundary between strata may not be as distinct as it is in Japanese. This topic would make for an interesting research question in future studies.

The previous studies and this dissertation have used nativized English loanwords in Korean as stimuli. Since these stimuli are already registered in Korean dictionaries, it is assumed that they have been in use for a relatively long time and are fully nativized in Korean. As a result, it is possible that Korean monolinguals produce epenthetic vowels in these loanwords as lexical vowels, resulting in formant values and durations similar to those of lexical vowels. Thus, it would be worthwhile to explore the production of epenthetic vowels in nonce words. For example, Korean monolinguals can be asked to read random English consonant clusters such as 'dtk'. Since /ɨ/ is the default epenthetic vowel in Korean, Korean monolinguals would try to use epenthetic /ɨ/ to break up English consonant clusters, and these epenthetic vowels can be compared with lexical vowels.

Lastly, it must be acknowledged that the participants exhibit a certain degree of bilingualism in this study. Technically, monolinguals are defined as individuals who can speak only one language (Kemp 2009). However, the scope of the term can be expanded. According to Escudero et al. (2014), monolinguals are individuals who (a) rely on their first language for everyday communication, (b) have not spent more than a month in a region where a different language is spoken, and (c) if they have received any second language instruction, it was minimal and largely confined to classroom settings. Their exposure to L2 is typically limited to lessons delivered by teachers who speak with an L1 accent, with an emphasis on reading and grammar rather than practical language use. To account for these contexts, the term "functional monolinguals" is also used. From this perspective, 25 out of 30 participants in the production study are considered monolinguals or functional monolinguals. However, 5 participants have lived in the United States for more than a month, even though they primarily use Korean in their daily lives, whether at school, work, or in social settings. Thus, this study acknowledges that the participants may exhibit some degree of bilingualism.

6.2 Perception of vowel epenthesis

This dissertation explored the linguistic factors which affect the native Korean listeners' perception on vowel epenthesis. Previous studies (Kang 2003; Kim 2008) based on the National Academy of Korean Language (National Institute of Korean Language 1991) found that epenthetic /ɨ/ occurs more frequently after the final stop in English CVC monosyllabic words when the final stop is released, voiced, or coronal. In addition, if a pre-final vowel is tense, epenthetic /ɨ/ is used more often in English CVC monosyllabic words.

Perceptual studies (Kang 2003; Kim 2008; Kim 2021, 2022; Kwon 2017) investigated these linguistic factors to validate that they perceptually influence the epenthetic /ɨ/ occurrence. The results confirmed that the release, voicing, and place of articulation of the final stops play an important role in the perception of the native Korean listeners' perception on /ɨ/ epenthesis. However, the tenseness of the pre-final vowel showed some opposite result in the perceptual studies. For example, Kim (2021) found that native Korean listeners were more likely to perceive /ɨ/ epenthesis when the pre-final vowel was tense rather than lax. However, a later perceptual study by Kim (2022) contradicted these findings, revealing that the tenseness had no effect on the perception of /ɨ/ epenthesis. A possible explanation for this discrepancy is the native Korean listeners' ability to perceive English tense-lax vowel distinctions. This aligns with research arguing that listeners' perceptual abilities in the source language influence loanword adaptation patterns (Best & Tyler 2007; Smith 2006; Wang 2023). Given that Korean lacks tense-lax vowel contrasts, many native Korean listeners struggle to differentiate between English tense and lax vowels (Kahng 2006; Kim 2012). Consequently, participants capable of distinguishing these contrasts may have perceived /ɨ/ epenthesis more frequently when the pre-final vowel is tense, whereas those unable to differentiate the contrasts did not show this pattern. Thus, this dissertation investigated the relationship between the ability to perceive English tense-lax vowel distinctions and the perception of /ɨ/ epenthesis rates. Participants in this study first took part in two discrimination tests specifically designed to evaluate their ability to distinguish between English lax and tense vowels, and then they took the ABX tests. The results were consistent with the previous studies (Kang 2003; Kim 2008; Kim 2021; Kwon 2017). The release, voicing, and place of articulation of the final stops in English CVC monosyllabic words play an important role in native Korean listeners' perception of /ɨ/ epenthesis. More importantly, there was a positive correlation between discrimination test scores and the tenseness of the pre-final vowel. The findings indicate that higher discrimination test scores are linked to an increased likelihood of perceiving /ɨ/ epenthesis when the pre-final vowel is tense. In other words, individuals with better listening abilities for English tense-lax vowel distinctions are more likely to perceive /ɨ/ epenthesis after a tense pre-final vowel. This positive correlation underscores the critical role of the ability to distinguish between English tense and lax vowels in the perceptual process of /ɨ/ epenthesis in English loanwords in Korean.

This dissertation also explored the linguistic factors affecting the native Korean listeners' perception of /i/ epenthesis. The results showed that native Korean listeners tended to perceive /i/ epenthesis more often when the final consonant was voiced and had a long noise duration. On the other hand, the tenseness of the pre-final vowel did not influence the perception of /i/ epenthesis, and no significant positive correlation was found between discrimination test scores and the tenseness of the pre-final vowel in /i/ epenthesis. When sounds in L2 are also present in a listener's L1, they become more perceptually prominent to the listener (Best 1995). This prominence may make such sounds easier to identify and interpret compared to sounds that are absent in the listener's L1. Phonetic features like consonant voicing which is present in Korean are more readily perceived and processed by native Korean listeners, whereas the English tense/lax vowel contrast which is unfamiliar tends to receive less attention. In this study, native Korean listeners may more easily perceive the familiar voicing feature when processing English nonce words. In contrast, unfamiliar tense/lax vowel features may receive less attention, leading native Korean listeners to rely on the strict phonological pattern that /i/ epenthesis always occurs after an English post-alveolar coda, regardless of their ability to distinguish English tense and lax vowels. Consequently, while consonant voicing and duration influenced the perceived rate of /i/ epenthesis, vowel tenseness had no impact. The phonological pattern that /i/ epenthesis always occurs after an English post-alveolar coda may also explain why the perceived rate of /i/ epenthesis is much higher than that of /ɨ/ epenthesis, both overall and within each effect. Native speakers possess knowledge of the distributional patterns and rules for their native lexicon and loanwords (Kwon 2017). That is, native Korean listeners are likely aware that /i/ epenthesis always occurs after an English post-alveolar coda, which leads to /i/ epenthesis being perceived more often than /ɨ/ epenthesis in the similar linguistic environments.

Native Korean speakers often use epenthetic vowels in English speech, and vowel epenthesis typically occurs when they produce English consonant clusters (Shin & Iverson 2014). A phonology-based explanation argues that vowel epenthesis in English speech occurs to break up English consonant clusters that do not exist in Korean (Lee 2008). In contrast, perceptual studies on epenthetic vowels show that native Korean listeners actually perceive epenthetic vowels in English speech. For example, this study found that native Korean listeners perceive epenthetic vowels depending on linguistic contexts, such as the release and voicing of the final consonant.

Perception and production are closely intertwined. According to motor theory (Liberman et al. 1967), listeners do not merely interpret sounds as acoustic signals; instead, they perceive them through the articulatory movements they might use to produce those sounds. Thus, perceptual training on foreign language sounds and structures can enhance production. For example, native Japanese speakers who participated in English /ɹ/–/l/ perceptual identification training pronounced these sounds more accurately (Bradlow et al. 1996; Lively et al. 1993). Also, native English speakers improved their pronunciation of French nasal vowels through perceptual training (Inceoglu 2016). This indicates that the perceptual knowledge acquired through perceptual training influences production. Thus, if native Korean listeners undergo perceptual identification training for English consonant clusters, they may enhance their production of these clusters and reduce their reliance on epenthetic vowels.

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APPENDICES

A English Proficiency Self-Rating Questionnaire (presented in Korean to participants)

Background Information

1. Name:

2. Year of birth:

3. Gender:

   a. Male
   b. Female

4. Please indicate the highest level of education you have received.

   a. Secondary school
   b. High school
   c. GED or equivalent 2-year college
   d. 4-year college
   e. Master's degree
   f. Doctorate

5. Do you have any hearing or vision problems that you are aware of?

   a. Yes
   b. No

Language background and experience

1. What is your native or first language? (The language you first spoke) If there is more than one, please indicate all languages you consider to be your native language. Do you speak any other languages?

	Language and years studied		Level				
	Language	Years Studied	Poor	Basic	Intermediate	Advanced	Fluent
Language 1							
Language 2							
Language 3							
Language 4							

2. Were you born in Korea?

a. Yes
b. No

3. Have you continuously lived in Korea since you were born?

a. Yes
b. No

4. If not, please indicate the time when you spent time in other countries.

Example: 2001 1 month in Mexico

5. Please rate your skills in English in the following areas. You can check the box.

	Speaking				
	Poor: I can use simple phrases and sentences	Basic: I can communicate in simple and routine tasks	Intermediate: I can connect phrases in a simple way in order to describe experiences and events	Advanced: I can take an active part in discussion in familiar contexts	Fluent: I can express myself fluently and spontaneously
Check here					
	Listening				
	Poor: I can recognise familiar words and very basic phrases	Basic: I can understand phrases and the highest frequency vocabulary	Intermediate: I can understand the main points of clear standard speech on familiar matters	Advanced: I can understand extended speech and lectures	Fluent: I have no difficulty in understanding any kind of spoken language
Check here					
	Reading				
	Poor: I can understand familiar names, words and very simple sentences	Basic: I can read very short, simple texts	Intermediate: I can understand texts that consist mainly of high frequency everyday language	Advanced: I can understand long and complex factual and literary texts	Fluent: I can read with ease virtually all forms of the written language
Check here					

	Writing				
	Poor: I can write a short, simple postcard or fill in simple forms	Basic: I can write short, simple notes and messages	Intermediate: I can write simple connected text on topic	Advanced: I can write clear, detailed text on a wide range of subjects related to my interest	Fluent: I can write clear, smoothly flowing text in an appropriate style

6. Did you receive any formal instruction in English?

a. Yes
b. No

7. How many years have you studied English?

8. Where have you studied English? How long? Were your teachers native speakers of English?

	Indicate number of months or years Months/Years	Native speaking teacher(s)?	
		Yes	No
Kindergarten			
Elementary school			
Middle school			
High school			
College/University			
Language school			
Private tutoring			
Study abroad			
Other (please explain)			

9. How many hours per week do you spend using English to

	0	1-2	3-4	5-6	7-8	9	10
talk on the telephone							
text							
browse or surf the internet							
write and read emails							
use social media (Facebook, Twitter)							

Chat online (google chat, ichat)							
use video calling software (Skype, Facetime)							
watch YouTube							
go to school (classes and instruction are in English)							
do homework							
prepare for quizzes and exams							
listen to language tapes							
read for fun							
read newspapers							
read magazines							
listen to music							
watch TV, video, and/or movies							
interact socially with friend your age							
interact socially with friends who are older than you							
interact at work (with colleagues, boss, clients, etc)							
interact at home (with family)							

10. Estimate how often you use English with each of the individuals listed below.

employers/superiors at work	Never	Less than Once a Month	Once a Month	Times a Month	Once a Week	Times a Week	Daily
teachers/professors							
grandparents							
parents							
extended family							
children							
brothers/sisters							
spouse/boyfriend/girlfriend							
friends who are your age							
friends who are older than you							

classmates/co-workers							
pets							

11. How often do you use English to

Percentage of total time						
	0%	10%	25%	50%	75%	100%
count, add, multiply, and do math in your head						
dream						
express affection						
express frustration or anger						
pray						
think out loud						

B Stimuli for passage-level read speech

Passage 1.

한국인의 운동에 대한 열정은 대단합니다. 예를 들어, 축구와 야구는 한국에서 인기가 많습니다. 축구 선수들은 멋진 슛과 드리블 또한 보여주며 사람들을 즐겁게 만듭니다. 예를 들어, 손흥민 선수는 독일에서 성공 후 잉글리시 프리미어 리그 또한 진출하여 사람들에게 크리스마스 선물같이 멋진 경기를 보여줍니다. 그라운드를 열심히 누비는 손흥민 선수를 보며 사람들은 대리 만족을 느끼기도 하며 공이 들어가면 서로 허그 나누며 즐거워합니다. 사람들은 시차로 인한 피곤함도 잊은 채 텔레비전과 유료 어플 또한 이용하여 손흥민 선수의 경기를 지켜봅니다. 야수 선수들 또한 멋진 스윙과 홈런을 보여줍니다. 미국의 월드 시리즈 최초 한국인 우승자 타이틀 주인공인 김병헌 선수도 사람들에게 큰 즐거움을 선사해 주었습니다. 자그맣고 가벼운 몇 그램짜리 공과 글러브 하나로 선수들은 사람들을 웃게 만듭니다.

손흥민 선수와 류현진 선수처럼 한국의 선수들은 여러 나라 선수와 함께 경쟁하며 환상적인 경기를 국민들에게 선사합니다. 한국의 선수들이 트로피 들어 올리는 모습을 볼 때 국민들은 자랑스러워합니다. 하지만 선수들의 성공은 하루아침에 이루어지는 것은 아닙니다. 선수들은 장기적인 계획을 세우고 하루하루 자신의 노력을 체크 후 다시 내일을 치열하게 살아갑니다.

선수들은 경기장 밖에서도 많은 영향을 사람들에게 미치고 있습니다. 예를 들어 유명 선수들은 브랜드 협업을 통하여 최신 트렌드 또한 주도하고 있습니다. 하지만 모든 스포츠 선수가 그러한 것은 아닙니다. 프라이버시를 잘 관리하지 못하면 스캔들 주인공이 되어 사람들에게 외면당하게 됩니다. 선수들은 부담감이 클수록 슬럼프 또한 겪기도 하지만, 극복하기 위해 큰 노력을 합니다. 정글 같은 배틀 속에서 살아남아 활약하고 있는 선수들에게 사람들은 많은 응원의 댓글과 서포트를 보냅니다.

선수들의 멋진 경기는 사람들에 심리적 만족감을 줄 뿐만 아니라 운동에 대한 모티브 또한 주고 있습니다. 그래서 한국 사람들은 커플, 친구, 그리고 가족 단위로 여러 다양한 운동을 많이 즐깁니다. 골프 그리고 싱글 사이클 같이 세계적으로 유명한 운동뿐만 아니라, 허들 그리고 크로스핏 같은 비인기 경기도 점차 관심을 받고 있습니다.

Passage 2.

나의 세 번째 소설의 기틀을 잡기 위해 이틀 밤을 꼬박 새운 나는 조심스럽게 산책길을 걷기 시작했다. 많은 시간을 함께 보내지 못한 것에 트집 잡으려는 그의 목소리가 여전히 귓가에 들리는 것 같았다. 언제나 생글 잘 웃던 그는 언제부턴가 시나브로 내 사랑의 크기를 의심했고 더 크게 사랑한다고 이야기해 주기를 바랐다. 가끔은 그는 브레이크 고장

난 자동차처럼 나를 몰아 붙이기도 했다. 그는 항상 나의 관심이 고프고, 그로 인해 나의 마음은 아프고 지쳐갔다. 처음에는 나도 이해하려 노력했지만 그를 향한 기대가 클수록 실망감도 점차 커졌다.

'그저 내가 틀린 걸까? 아니면 이제는 틀림없이 서로 다른 길을 가야 하는 걸까...?'

산책길은 나의 마음과는 다르게 흐드러진 예쁜 들꽃들과 바글바글 작고 귀여운 꿀벌들로 가득 차 있었다. 몽클몽클 아침 안개가, 산들 불어오는 아침 바람이 탁 트인 산책길을 가득 메웠고, 간드러진 새소리가 나의 귀를 어루만졌다. 어디선가 달콤한 메이플 시럽 향이 나는 것만 같았다. 하지만 이 미라클 같은 산책길도 여전히 조각나 널브러진 내 마음을 위로하기에는 충분하지 않았다.

'이 길 끝에서 나는 여전히 그의 사랑이 고플까? 그리고 여전히 마음도 아플까?'

나는 스스로 내 마음을 들추어 보았다. 복잡한 마음을 글쓰기로 정리하고 싶다는 생각이 갑자기 들었다. 나는 나무 테이블 앞의 그네에 앉아 노트 가득히 내 마음을 적어 내려갔다. 여러 가지 감정이 몰려와 뭉클뭉클 복받쳤다. 평생 글짓기를 하며 깨달은 단순한 진리는 잡을수록 놓아야 할 것이 있고, 접을수록 펼쳐야 할 마음이 있다는 것이다. 이 단순한 진리가 나를 위로했다. 그는 내가 더 이상 잡을 사람이 아니며 그를 향한 마음은 접을 것이 맞았다.
복잡한 생각을 글로 정리하니 나의 무클하며 썩어갔던 감정이 다시 반들반들 살아나는 것이 느껴졌고 그를 향한 감정은 나의 클클대는 웃음으로 흩어져 갔다. 이제 그와의 드라마 같았던 지난 일들을 다 잊겠노라 다짐했다. 나는 더 이상 아플 일도 슬플 일도 없기를 기대하며 일어났다.

Epenthetic /ɨ/	
12 epenthetic /ɨ/ in non-final CV syllable structure	
그램 [kɨlæm]	'gram'
그라운드 [kɨlaunti]	'ground'
드리블 [tɨlipɨl]	'dribble'
드라마 [tɨlama]	'drama'
브랜드 [pɨlæntɨ]	'brand'
브레이크 [pɨleik^{h}ɨ]	'break'
크리스마스 [k^{h}ɨlis'ɨmas'ɨ]	'Christmas'

크로스 [k^{h}ɨlos’ɨ]	‘cross’
트렌드 [t^{h}ɨlɛntɨ]	‘trend’
트로피 [t^{h}ɨlop^{h}i]	‘trophy’
프리미어 [p^{h}ɨlimiʌ]	‘premier’
프라이버시 [p^{h}ɨlɑipʌs’i]	‘privacy’
12 epenthetic /ɨ/ in final CV syllable structure	
리그 [likɨ]	‘league’
허그 [hʌkɨ]	‘hug’
브레이크 [pɨlɛik^{h}ɨ]	‘break’
체크 [tʃ^{h}ɛk^{h}ɨ]	‘check’
월드 [wʌltɨ]	‘world’
트렌드 [t^{h}ɨlɛntɨ]	‘trend’
노트 [not^{h}ɨ]	‘note’
서포트 [s’ʌp^{h}ot^{h}ɨ]	‘support’
모티브 [mot^{h}ipɨ]	‘motive’
글러브 [kɨllʌpɨ]	‘globe’
골프 [kolp^{h}ɨ]	‘golf’
슬럼프 [sɨllʌp^{h}ɨ]	‘slump’
12 epenthetic /ɨ/ in final CVC syllable structure	
정글 [tʃʌŋkɨl]	‘jungle’
싱글 [s’iŋkɨl]	‘single’
사이클 [s’ɑik^{h}ɨl]	‘cycle’
미라클 [milɑk^{h}ɨl]	‘miracle’
허들 [hʌtɨl]	‘hurdle’
스캔들 [sɨk^{h}æntɨl]	‘scandal’
타이틀 [t^{h}ɑit^{h}ɨl]	‘title’
배틀 [pæt^{h}ɨl]	‘battle’
드리블 [tɨlipɨl]	‘dribble’
테이블 [t^{h}ɛipɨl]	‘table’
커플 [k^{h}ʌp^{h}ɨl]	‘couple’
어플 [ʌp^{h}ɨl]	‘application’

Lexical /ɨ/	
12 lexical /ɨ/ in non-final CV syllable structure	
그저 [kɨtʃʌ]	'just'
그네 [kɨnɛ]	'swing'
흐드러진 [hɨtɨlʌtʃin]	'in full bloom'
간드러진 [kantɨlʌtʃin]	'melodious'
널브러진 [nʌlpɨlʌtʃin]	'scatter'
시나브로 [sinɑpɨlo]	'slowly but steadily'
크기 [kʰɨki]	'size'
크게 [kʰɨkɛ]	'big'
트인 [tʰɨin]	'open'
트집 [tʰɨtʃip]	'nitpick'
고프고 [gopʰɨko]	'hungry and'
아프고 [ɑpʰɨko]	'sick and'
12 lexical /ɨ/ in final CVC syllable structure	
생글 [sæŋkɨl]	'smiling brightly'
바글 [pɑkɨl]	'teeming'
몽클 [moŋkʰɨl]	'overwhelmed'
뭉클 [muŋkʰɨl]	'heartwarming'
반들 [pantɨl]	'glossy'
산들 [santɨl]	'gently'
이틀 [itʰɨl]	'two days'
기틀 [kitʰɨl]	'foundation'
잡을 [tʃɑpʰɨl]	'hold on (future)'
접을 [tʃʌpʰɨl]	'hold back feelings (future)'
아플 [ɑpʰɨl]	'sick (future)'
슬플 [sɨlpʰɨl]	'sad (future)'
12 lexical /ɨ/ in non-final CVC syllable structure	
글쓰기 [kɨls'ɨki]	'writing'
글짓기 [kɨltʃidki]	'writing'
무클하며 [mukʰɨlhɑmjʌ]	'rotting and becoming mushy'
클수록 [kʰɨls'ulok]	'the bigger…'

들리는 [tɨlkinɨn]	‘hearing’
들추어 [tɨltʃʰuʌ]	‘looking into’
틀림없이 [tʰɨllimʌps’i]	‘definitely’
틀린 [tʰɨllin]	‘wrong’
잡을수록 [tʃapɨls’ulok]	‘the more one holds on’
접을수록 [tʃʌpɨls’ulok]	‘the more one holds back feelings’
고플까 [kopʰɨlk’a]	‘hungry (question)’
아플까 [apʰɨlk’a]	‘sick (question)’

C Epenthetic /ɨ/ and epenthetic /i/ stimuli for different speech rates

Epenthetic /ɨ/	
12 epenthetic /ɨ/ in non-final CV syllable structure	
그램 [kɨlæm]	‘gram’
그룹 [kɨlup]	‘group’
드림 [tɨlim]	‘dream’
드럼 [tɨlʌm]	‘drum’
브롬 [pɨlom]	‘brom(ine)’
브로 [pɨlo]	‘bro(ther)’
크랩 [k^{h}ɨlæp]	‘crab’
크림 [k^{h}ɨlim]	‘cream’
트리 [t^{h}ɨli]	‘tree’
트랩 [t^{h}ɨlæp]	‘trap’
프로 [p^{h}ɨlo]	‘pro(gram)’
프리 [p^{h}ɨli]	‘free’
12 epenthetic /ɨ/ in final CV syllable structure	
도그 [tokɨ]	‘dog’
머그 [mʌkɨ]	‘mug’
노크 [nok^{h}ɨ]	‘knock’
다크 [tɑk^{h}ɨ]	‘dark’
모드 [motɨ]	‘mode’
카드 [k^{h}ɑtɨ]	‘card’
보트 [pot^{h}ɨ]	‘boat’
미트 [mit^{h}ɨ]	‘meat’
커브 [k^{h}ʌpɨ]	‘curve’
허브 [hʌpɨ]	‘hurb’
로프 [lop^{h}ɨ]	‘rope’
터프 [t^{h}ʌp^{h}ɨ]	‘tough’
12 epenthetic /ɨ/ in final CVC syllable structure	
고글 [kokɨl]	‘goggles’
이글 [ikɨl]	‘eagle’
서클 [sʌk^{h}ɨl]	‘circle’

태클 [tʰækʰɨl]	‘tackle’
누들 [nutɨl]	‘noodle’
미들 [mitɨl]	‘middle’
리틀 [litʰɨl]	‘little’
셔틀 [sjʌtʰɨl]	‘shuttle’
더블 [tʌpɨl]	‘double’
마블 [mɑpɨl]	‘marble’
애플 [æpʰɨl]	‘apple’
와플 [wɑpʰɨl]	‘waffle’
Epenthetic /i/	
10 epenthetic /i/ after final /tʃ/	
라지 [lɑtʃi]	‘large’
루지 [lutʃi]	‘luge’
비지 [pitʃi]	‘busy’
배지 [pætʃi]	‘badge’
이지 [itʃi]	‘easy’
에지 [ɛtʃi]	‘edge’
조지 [tʃotʃi]	‘George’
저지 [tʃʌtʃi]	‘judge’
피지 [pʰitʃi]	‘Fiji’
퍼지 [pʰʌtʃi]	‘fudge’
10 epenthetic /i/ after final /tʃʰ/	
마치 [mɑtʃʰi]	‘march’
매치 [mætʃʰi]	‘match’
워치 [wʌtʃʰi]	‘watch’
아치 [ɑtʃʰi]	‘arch’
터치 [tʰʌtʃʰi]	‘touch’
토치[tʰotʃʰi]	‘torch’
피치 [pʰitʃʰi]	‘pitch’
패치 [pʰætʃʰi]	‘patch’
히치 [hitʃʰi]	‘hitch’
해치 [hætʃʰi]	‘hatch’

D Lexical /ɨ/ and lexical /i/ stimuli for different speech rates

Lexical /ɨ/	
12 lexical /ɨ/ in non-final CV syllable structure	
그림 [kɨlim]	‘picture’
그네 [kɨnɛ]	‘swing’
드글 [tɨkɨl]	‘swarming with’
드문 [tɨmun]	‘rare’
널브리다 [nʌlpɨliɑ]	‘scatter’
시나브로 [sinɑpɨlo]	‘slowly but steadily’
크기 [k^{h}ɨki]	‘size’
크다 [k^{h}ɨtɑ]	‘big’
트림 [t^{h}ɨlim]	‘burp’
트집 [t^{h}ɨtʃip]	‘nitpick’
배고프다 [pægop^{h}ɨtɑ]	‘hungry’
애달프다 [ætɑlp^{h}ɨtɑ]	‘heartrending’
12 lexical /ɨ/ in final CVC syllable structure	
서글 [sʌkɨl]	‘warm and friendly demeanor’
지글 [tʃikɨl]	‘sound of something frying’
뭉클 [muŋk^{h}ɨl]	‘emotional’
수클 [suk^{h}ɨl]	‘writing applied well after learning’
구들 [kutɨl]	‘Korean underfloor heating system’
버들 [pʌtɨl]	‘willow tree’
비틀 [it^{h}ɨl]	‘staggering’
베틀 [pɛt^{h}ɨl]	‘loom for weaving’
입을 [ip^{h}ɨl]	‘wear (future)’
깁을 [kip^{h}ɨl]	‘sew (future)’
헤플 [hɛp^{h}ɨl]	‘wasteful (future)’
슬플 [sɨlp^{h}ɨl]	‘sad (future)’
12 lexical /ɨ/ in non-final CVC syllable structure	
글자 [kɨltʃ’ɑ]	‘letter’
글씨 [kɨls’i]	‘handwriting’
무클하다 [muk^{h}ɨlhɑtɑ]	‘rotting and becoming mushy’

클클 [k^{h}ɨlk^{h}ɨl]	‘chuckling’
들판 [tɨlp^{h}ɑn]	‘field’
들깨 [tɨlk’æ]	‘perilla seed’
틀다 [t^{h}ɨltɑ]	‘turn’
틀니 [t^{h}ɨlli]	‘denture’
씹을수록 [s’ipɨls’ulok]	‘the more one chews’
잡을수록 [tʃɑpɨls’ulok]	‘the more one holds on’
고플세라 [kop^{h}ɨls’ɛla]	‘hungry (worry)’
아플세라 [ɑp^{h}ɨls’ɛla]	‘sick (worry)’
Lexical /i/	
10 lexical /i/ after final /tʃ/	
가지 [kɑtʃi]	‘branch’
거지 [kʌtʃi]	‘beggar’
무지 [mutʃi]	‘ignorance’
미지 [mitʃi]	‘unknown’
사지 [sɑtʃi]	‘limbs’
소지 [sotʃi]	‘possession’
오지 [otʃi]	‘outback’
유지 [jutʃi]	‘maintenance’
차지 [tʃ^{h}ɑtʃi]	‘occupation’
처지 [tʃ^{h}ʌtʃi]	‘position’
10 lexical /i/ after final /tʃ^{h}/	
가치 [kɑtʃ^{h}i]	‘value’
구치 [kutʃ^{h}i]	‘custody’
비치 [pitʃ^{h}i]	‘equipping’
배치 [pætʃ^{h}i]	‘arrangement’
사치 [sɑtʃ^{h}i]	‘luxury’
수치 [sutʃ^{h}i]	‘shame’
이치 [itʃ^{h}i]	‘reason’
어치 [ʌtʃ^{h}i]	‘worth of’
차치 [tʃ^{h}atʃ^{h}i]	‘leaving aside’
처치 [tʃ^{h}ʌtʃ^{h}i]	‘handling’

E Statistical results at different speech rates

E1. Tukey's pairwise comparisons of durations by gender, word position, and syllable structure in passage-level read speech

Origin	Comparison (gender)	Estimate	t-value	Pr (>|t|)
Epenthetic /ɨ/	Male – Female	−0.0049	−2.0412	0.0435 *
Lexical /ɨ/	Male – Female	−0.0056	−2.3333	0.0261 *
Origin	Comparison (word position)	Estimate	t-value	Pr (>|t|)
Epenthetic /ɨ/	Non – Final	−0.0085	−2.7419	0.0062 **
Lexical /ɨ/	Non – Final	−0.0098	−3.1429	0.0031 **
Origin	Comparison (syllable structure)	Estimate	t-value	Pr (>|t|)
Epenthetic /ɨ/	Open – Closed	0.0101	3.3030	0.0014 **
Lexical /ɨ/	Open – Closed	0.0113	3.9286	0.0009 **

E2. Tukey's pairwise comparisons of durations by origin at normal speech rate

Comparison (origin)	Estimate	t-value	Pr (>|t|)
Epenthetic /ɨ/ – Lexical /ɨ/	−0.001	−0.167	0.9301

E3. Tukey's pairwise comparisons of F1 and F2 by origin for female and male speakers at normal speech rate

Female	F1	Comparison (origin)	Estimate	t-value	Pr (>|t|)
		Epenthetic /i/ – Lexical /i/	−11.581	−0.229	0.8181
	F2	Comparison (origin)	Estimate	t-value	Pr (>|t|)
		Epenthetic /i/ – Lexical /i/	12.789	0.057	0.6159
Male	F1	Comparison (origin)	Estimate	t-value	Pr (>|t|)
		Epenthetic /i/ – Lexical /i/	−10.750	−0.231	0.6199
	F2	Comparison (origin)	Estimate	t-value	Pr (>|t|)
		Epenthetic /i/ – Lexical /i/	−15.561	−0.079	0.9361

E4. Tukey's pairwise comparisons of durations by origin at normal speech rate

Comparison (origin)	Estimate	t-value	Pr (>|t|)
Epenthetic /i/ – Lexical /i/	0.001	0.004	0.9640

E5. Tukey's pairwise comparisons of durations by gender at normal speech rate

Origin	Comparison (gender)	Estimate	t-value	Pr (>|t|)
Epenthetic /i/	Female – Male	0.008	1.999	0.0399 *
Lexical /i/	Female – Male	0.005	0.002	0.0401 *

E6. Tukey's pairwise comparisons of durations by origin at fast speech rate

Comparison (origin)	Estimate	t-value	Pr (>|t|)
Epenthetic /ɨ/ – lexical /ɨ/	0.001	0.125	0.9011

E7. Tukey's pairwise comparisons of durations by origin at fast speech rate

Comparison (origin)	Estimate	t-value	Pr (>|t|)
Epenthetic /i/ – Lexical /i/	0.001	1.801	0.0719

E8 Tukey's pairwise comparisons of durations by gender at fast speech rate

Origin	Comparison (gender)	Estimate	t-value	Pr (>|t|)
Epenthetic /i/	Female – Male	0.006	2.120	0.0357 *
Lexical /i/	Female – Male	0.007	2.566	0.0124 *

F Stimuli for two English tense and lax discrimination tests

First Discrimination Test	Tense /i/	Lax /ɪ/
	Beat	Bit
	Beach	Bitch
	Bean	Bin
	Cheap	Chip
	Feel	Fill
	Heat	Hit
	Peach	Pitch
	Peal	Pill
	Peak	Pick
	Seek	Sick
	Seep	Sip
	Teen	Tin
	Tense /u/	**Lax /ʊ/**
	Fool	Full
	Luke	Look
	Pool	Pull
Second Discrimination Test	**Tense /i/**	**Lax /ɪ/**
	[hib]	[hɪb]
	[hidʒ]	[hɪdʒ]
	[zid]	[zɪd]
	[zik]	[zɪk]
	[zib]	[zɪb]
	[ziʧ]	[zɪʧ]
	[ʧid]	[ʧɪd]
	[ʧig]	[ʧɪg]
	[ʧib]	[ʧɪb]
	[vit]	[vɪt]
	[vik]	[vɪk]
	[vib]	[vɪb]
	[viʧ]	[vɪʧ]
	[vidʒ]	[vɪdʒ]
	Tense /u/	**Lax /ʊ/**
	[hug]	[hʊg]
	[hub]	[hʊb]
	[hudʒ]	[hʊdʒ]
	[zud]	[zʊd]
	[zug]	[zʊg]
	[zup]	[zʊp]
	[zub]	[zʊb]
	[zuʧ]	[zʊʧ]
	[zudʒ]	[zʊdʒ]
	[ʧut]	[ʧʊt]
	[ʧud]	[ʧʊd]

	[ʧug]	[ʧʊg]
	[ʧup]	[ʧʊp]
	[ʧub]	[ʧʊb]
	[dʒug]	[dʒʊg]
	[dʒup]	[dʒʊp]
	[dʒub]	[dʒʊb]
	[dʒuʧ]	[dʒʊʧ]
	[vut]	[vʊt]
	[vup]	[vʊp]
	[vuk]	[vʊk]
	[vuʧ]	[vʊʧ]

G   196 ABX stimuli for /ɨ/ epenthesis

Korean A and B			English X
Without epenthesis		With epenthesis	
1.	[tik]	[tikʰɨ]	[dik]
2.	[tik]	[tikʰɨ]	[dik̚]
3.	[tip]	[tipɨ]	[dib]
4.	[tip]	[tipɨ]	[dib̚]
5.	[tit]	[titʰɨ]	[dɪt]
6.	[tit]	[titʰɨ]	[dɪt̚]
7.	[tip]	[tipɨ]	[dɪb]
8.	[tip]	[tipɨ]	[dɪb̚]
9.	[tut]	[tutʰɨ]	[dut]
10.	[tut]	[tutʰɨ]	[dut̚]
11.	[tuk]	[tukʰɨ]	[duk]
12.	[tuk]	[tukʰɨ]	[duk̚]
13.	[tup]	[tupʰɨ]	[dup]
14.	[tup]	[tupʰɨ]	[dup̚]
15.	[tut]	[tutʰɨ]	[dʊt]
16.	[tut]	[tutʰɨ]	[dʊt̚]
17.	[tut]	[tutɨ]	[dʊd]
18.	[tut]	[tutɨ]	[dʊd̚]
19.	[tuk]	[tukʰɨ]	[dʊk]
20.	[tuk]	[tukʰɨ]	[dʊk̚]
21.	[tuk]	[tukɨ]	[dʊg]
22.	[tuk]	[tukɨ]	[dʊg̚]
23.	[tup]	[tupʰɨ]	[dʊp]
24.	[tup]	[tupʰɨ]	[dʊp̚]
25.	[tup]	[tupɨ]	[dʊb]
26.	[tup]	[tupɨ]	[dʊb̚]
27.	[tʰit]	[tʰitɨ]	[tid]
28.	[tʰit]	[tʰitɨ]	[tid̚]
29.	[tʰik]	[tʰikʰɨ]	[tik]
30.	[tʰik]	[tʰikʰɨ]	[tik̚]
31.	[tʰik]	[tʰikɨ]	[tig]
32.	[tʰik]	[tʰikɨ]	[tig̚]
33.	[tʰip]	[tʰipɨ]	[tib]
34.	[tʰip]	[tʰipɨ]	[tib̚]
35.	[tʰit]	[tʰitɨ]	[tɪd]
36.	[tʰit]	[tʰitɨ]	[tɪd̚]
37.	[tʰip]	[tʰipɨ]	[tɪb]
38.	[tʰip]	[tʰipɨ]	[tɪb̚]
39.	[tʰut]	[tʰutɨ]	[tud]
40.	[tʰut]	[tʰutɨ]	[tud̚]
41.	[tʰuk]	[tʰukʰɨ]	[tuk]
42.	[tʰuk]	[tʰukʰɨ]	[tuk̚]

43. [t^{h}ut]	[tut^{h}ɨ]	[tʊt]
44. [t^{h}ut]	[t^{h}ut^{h}ɨ]	[tʊt˺]
45. [t^{h}ut]	[t^{h}utɨ]	[tʊd]
46. [t^{h}ut]	[t^{h}utɨ]	[tʊd˺]
47. [t^{h}uk]	[t^{h}ukɨ]	[tʊg]
48. [t^{h}uk]	[t^{h}ukɨ]	[tʊg˺]
49. [t^{h}up]	[t^{h}up^{h}ɨ]	[tʊp]
50. [t^{h}up]	[t^{h}up^{h}ɨ]	[tʊp˺]
51. [t^{h}up]	[t^{h}upɨ]	[tʊb]
52. [t^{h}up]	[t^{h}upɨ]	[tʊb˺]
53. [kit]	[kitɨ]	[gid]
54. [kit]	[kitɨ]	[gid˺]
55. [kip]	[kip^{h}ɨ]	[gip]
56. [kip]	[kip^{h}ɨ]	[gip˺]
57. [kip]	[kipɨ]	[gib]
58. [kip]	[kipɨ]	[gib˺]
59. [kit]	[kitɨ]	[gɪd]
60. [kit]	[kitɨ]	[gɪd˺]
61. [kik]	[kik^{h}ɨ]	[gɪk]
62. [kik]	[kik^{h}ɨ]	[gɪk˺]
63. [kip]	[kip^{h}ɨ]	[gɪp]
64. [kip]	[kip^{h}ɨ]	[gɪp˺]
65. [kuk]	[kuk^{h}ɨ]	[guk]
66. [kuk]	[kuk^{h}ɨ]	[guk˺]
67. [kuk]	[kukɨ]	[gug]
68. [kuk]	[kukɨ]	[gug˺]
69. [kup]	[kup^{h}ɨ]	[gup]
70. [kup]	[kup^{h}ɨ]	[gup˺]
71. [kup]	[kupɨ]	[gub]
72. [kup]	[kupɨ]	[gub˺]
73. [kut]	[kut^{h}ɨ]	[gʊt]
74. [kut]	[kut^{h}ɨ]	[gʊt˺]
75. [kuk]	[kukɨ]	[gʊg]
76. [kuk]	[kukɨ]	[gʊg˺]
77. [kup]	[kup^{h}ɨ]	[gʊp]
78. [kup]	[kup^{h}ɨ]	[gʊp˺]
79. [kup]	[kupɨ]	[gʊb]
80. [kup]	[kupɨ]	[gʊb˺]
81. [k^{h}it]	[k^{h}it^{h}ɨ]	[kit]
82. [k^{h}it]	[k^{h}it^{h}ɨ]	[kit˺]
83. [k^{h}ik]	[k^{h}ik^{h}ɨ]	[kik]
84. [k^{h}ik]	[k^{h}ik^{h}ɨ]	[kik˺]
85. [k^{h}ik]	[k^{h}ikɨ]	[kig]
86. [k^{h}ik]	[k^{h}ikɨ]	[kig˺]
87. [k^{h}ip]	[k^{h}ipɨ]	[kib]
88. [k^{h}ip]	[k^{h}ipɨ]	[kib˺]

89. [kʰik]	[kʰikɨ]	[kɪg]
90. [kʰik]	[kʰikɨ]	[kɪg˺]
91. [kʰip]	[kʰipɨ]	[kɪb]
92. [kʰip]	[kʰipɨ]	[kɪb˺]
93. [kʰut]	[kʰutɨ]	[kud]
94. [kʰut]	[kʰutɨ]	[kud˺]
95. [kʰuk]	[kʰukʰɨ]	[kuk]
96. [kʰuk]	[kʰukʰɨ]	[kuk˺]
97. [kʰuk]	[kʰukɨ]	[kug]
98. [kʰuk]	[kʰukɨ]	[kug˺]
99. [kʰup]	[kʰupɨ]	[kub]
100. [kʰup]	[kʰupɨ]	[kub˺]
101. [kʰut]	[kʰutʰɨ]	[kʊt]
102. [kʰut]	[kʰutʰɨ]	[kʊt˺]
103. [kʰuk]	[kʰukɨ]	[kʊg]
104. [kʰuk]	[kʰukɨ]	[kʊg˺]
105. [kʰup]	[kʰupʰɨ]	[kʊp]
106. [kʰup]	[kʰupʰɨ]	[kʊp˺]
107. [kʰup]	[kʰupɨ]	[kʊb]
108. [kʰup]	[kʰupɨ]	[kʊb˺]
109. [pik]	[pikɨ]	[big]
110. [pik]	[pikɨ]	[big˺]
111. [pip]	[pipɨ]	[bib]
112. [pip]	[pipɨ]	[bib˺]
113. [pik]	[pikʰɨ]	[bɪk]
114. [pik]	[pikʰɨ]	[bɪk˺]
115. [put]	[putɨ]	[bud]
116. [put]	[putɨ]	[bud˺]
117. [puk]	[pukɨ]	[bug]
118. [puk]	[pukɨ]	[bug˺]
119. [put]	[putʰɨ]	[bʊt]
120. [put]	[putʰɨ]	[bʊt˺]
121. [put]	[putɨ]	[bʊd]
122. [put]	[putɨ]	[bʊd˺]
123. [puk]	[pukʰɨ]	[bʊk]
124. [puk]	[pukʰɨ]	[bʊk˺]
125. [puk]	[pukɨ]	[bʊg]
126. [puk]	[pukɨ]	[bʊg˺]
127. [pup]	[pupʰɨ]	[bʊp]
128. [pup]	[pupʰɨ]	[bʊp˺]
129. [pup]	[pupɨ]	[bʊb]
130. [pup]	[pupɨ]	[bʊb˺]
131. [pʰip]	[pʰipɨ]	[pib]
132. [pʰip]	[pʰipɨ]	[pib˺]
133. [pʰip]	[pʰipɨ]	[pɪb]
134. [pʰip]	[pʰipɨ]	[pɪb˺]

135.	[pʰut]	[pʰutʰɨ]	[put]
136.	[pʰut]	[pʰutʰɨ]	[put˺]
137.	[pʰut]	[pʰutɨ]	[pud]
138.	[pʰut]	[pʰutɨ]	[pud˺]
139.	[pʰuk]	[pʰukʰɨ]	[puk]
140.	[pʰuk]	[pʰukʰɨ]	[puk˺]
141.	[pʰuk]	[pʰukɨ]	[pug]
142.	[pʰuk]	[pʰukɨ]	[pug˺]
143.	[pʰup]	[pʰupɨ]	[pub]
144.	[pʰup]	[pʰupɨ]	[pub˺]
145.	[pʰut]	[pʰutɨ]	[pʊd]
146.	[pʰut]	[pʰutɨ]	[pʊd˺]
147.	[pʰuk]	[pʰukʰɨ]	[pʊk]
148.	[pʰuk]	[pʰukʰɨ]	[pʊk˺]
149.	[pʰuk]	[pʰukɨ]	[pʊg]
150.	[pʰuk]	[pʰukɨ]	[pʊg˺]
151.	[pʰup]	[pʰupʰɨ]	[pʊp]
152.	[pʰup]	[pʰupʰɨ]	[pʊp˺]
153.	[pʰup]	[pʰupɨ]	[pʊb]
154.	[pʰup]	[pʰupɨ]	[pʊb˺]
155.	[mik]	[mikɨ]	[mig]
156.	[mik]	[mikɨ]	[mig˺]
157.	[mip]	[mipʰɨ]	[mip]
158.	[mip]	[mipʰɨ]	[mip˺]
159.	[mip]	[mipɨ]	[mib]
160.	[mip]	[mipɨ]	[mib˺]
161.	[mit]	[mitʰɨ]	[mɪt]
162.	[mit]	[mitʰɨ]	[mɪt˺]
163.	[mit]	[mitɨ]	[mɪd]
164.	[mit]	[mitɨ]	[mɪd˺]
165.	[mik]	[mikʰɨ]	[mɪk]
166.	[mik]	[mikʰɨ]	[mɪk˺]
167.	[mip]	[mipʰɨ]	[mɪp]
168.	[mip]	[mipʰɨ]	[mɪp˺]
169.	[mup]	[mupʰɨ]	[mup]
170.	[mup]	[mupʰɨ]	[mup˺]
171.	[mut]	[mutʰɨ]	[mʊt]
172.	[mut]	[mutʰɨ]	[mʊt˺]
173.	[mut]	[mutɨ]	[mʊd]
174.	[mut]	[mutɨ]	[mʊd˺]
175.	[muk]	[mukɨ]	[mʊg]
176.	[muk]	[mukɨ]	[mʊg˺]
177.	[mup]	[mupʰɨ]	[mʊp]
178.	[mup]	[mupʰɨ]	[mʊp˺]
179.	[mup]	[mupɨ]	[mʊb]
180.	[mup]	[mupɨ]	[mʊb˺]

181.	[sik]	[sikɨ]	[sig]
182.	[sik]	[sikɨ]	[sig˺]
183.	[sip]	[sipɨ]	[sib]
184.	[sip]	[sipɨ]	[sib˺]
185.	[sut]	[sutɨ]	[sud]
186.	[sut]	[sutɨ]	[sud˺]
187.	[suk]	[sukɨ]	[sug]
188.	[sut]	[sukɨ]	[sug˺]
189.	[sup]	[supɨ]	[sub]
190.	[sup]	[supɨ]	[sub˺]
191.	[sut]	[sutɨ]	[sʊd]
192.	[sut]	[sutɨ]	[sʊd˺]
193.	[suk]	[sukɨ]	[sʊg]
194.	[suk]	[sukɨ]	[sʊg˺]
195.	[sup]	[supɨ]	[sʊb]
196.	[sup]	[supɨ]	[sʊb˺]

H 64 ABX stimuli for /i/ epenthesis

Korean A and B		**English X**
Without epenthesis	With epenthesis	
1. [tit]	[titʃʰi]	[ditʃː]
2. [tit]	[titʃʰi]	[dit͡ʃ]
3. [tit]	[titʃʰi]	[dɪtʃː]
4. [tit]	[titʃʰi]	[dɪt͡ʃ]
5. [tit]	[titʃi]	[didʒː]
6. [tit]	[titʃi]	[did͡ʒ]
7. [tit]	[titʃi]	[dɪdʒː]
8. [tit]	[titʃi]	[dɪd͡ʒ]
9. [tut]	[tutʃʰi]	[dutʃː]
10. [tut]	[tutʃʰi]	[dut͡ʃ]
11. [tut]	[tutʃʰi]	[dʊtʃː]
12. [tut]	[tutʃʰi]	[dʊt͡ʃ]
13. [tut]	[tutʃi]	[dudʒː]
14. [tut]	[tutʃi]	[dud͡ʒ]
15. [tut]	[tutʃi]	[dʊdʒː]
16. [tut]	[tutʃi]	[dʊd͡ʒ]
17. [tʰut]	[tʰutʃʰi]	[tutʃː]
18. [tʰut]	[tʰutʃʰi]	[tut͡ʃ]
19. [tʰut]	[tʰutʃʰi]	[tʊtʃː]
20. [tʰut]	[tʰutʃʰi]	[tʊt͡ʃ]
21. [tʰut]	[tʰutʃi]	[tudʒː]
22. [tʰut]	[tʰutʃi]	[tud͡ʒ]
23. [tʰut]	[tʰutʃi]	[tʊdʒː]
24. [tʰut]	[tʰutʃi]	[tʊd͡ʒ]
25. [kit]	[kitʃʰi]	[gitʃː]
26. [kit]	[kitʃʰi]	[git͡ʃ]
27. [kit]	[kitʃʰi]	[gɪtʃː]
28. [kit]	[kitʃʰi]	[gɪt͡ʃ]
29. [kit]	[kitʃi]	[gidʒː]
30. [kit]	[kitʃi]	[gid͡ʒ]
31. [kit]	[kitʃi]	[gɪdʒː]
32. [kit]	[kitʃi]	[gɪd͡ʒ]
33. [kut]	[kutʃʰi]	[gutʃː]
34. [kut]	[kutʃʰi]	[gut͡ʃ]
35. [kut]	[kutʃʰi]	[gʊtʃː]
36. [kut]	[kutʃʰi]	[gʊt͡ʃ]
37. [kut]	[kutʃi]	[gudʒː]

38. [kut]	[kutʃi]	[gud͡ʒ]
39. [kut]	[kutʃi]	[gʊdʒː]
40. [kut]	[kutʃi]	[gʊd͡ʒ]
41. [kʰit]	[kʰitʃi]	[kidʒː]
42. [kʰit]	[kʰitʃi]	[kid͡ʒ]
43. [kʰit]	[kʰitʃi]	[kɪdʒː]
44. [kʰit]	[kʰitʃi]	[kɪd͡ʒ]
45. [kʰut]	[kʰutʃi]	[kudʒː]
46. [kʰut]	[kʰutʃi]	[kud͡ʒ]
47. [kʰut]	[kʰutʃi]	[kʊdʒː]
48. [kʰut]	[kʰutʃi]	[kʊd͡ʒ]
49. [pit]	[pitʃi]	[bidʒː]
50. [pit]	[pitʃi]	[bid͡ʒ]
51. [pit]	[pitʃi]	[bɪdʒː]
52. [pit]	[pitʃi]	[bɪd͡ʒ]
53. [put]	[putʃi]	[budʒː]
54. [put]	[putʃi]	[bud͡ʒ]
55. [put]	[putʃi]	[bʊdʒː]
56. [put]	[putʃi]	[bʊd͡ʒ]
57. [pʰit]	[pʰitʃi]	[pidʒː]
58. [pʰit]	[pʰitʃi]	[pid͡ʒ]
59. [pʰit]	[pʰitʃi]	[pɪdʒː]
60. [pʰit]	[pʰitʃi]	[pɪd͡ʒ]
61. [pʰut]	[pʰutʃi]	[pudʒː]
62. [pʰut]	[pʰutʃi]	[pud͡ʒ]
63. [pʰut]	[pʰutʃi]	[pʊdʒː]
64. [pʰut]	[pʰutʃi]	[pʊd͡ʒ]