Production and Perception of English Word-final Stops by Korean Speakers

A Dissertation Presented

by

Jungyeon Kim

to

The Graduate School

in Partial Fulfillment of the

Requirements

for the Degree of

Doctor of Philosophy

in

Linguistics

Stony Brook University

August 2018

Stony Brook University

The Graduate School

Jungyeon Kim

We, the dissertation committee for the above candidate for the

Doctor of Philosophy degree, hereby recommend

acceptance of this dissertation.

Ellen Broselow – Dissertation Co-Advisor
Professor, Department of Linguistics

Christina Y. Bethin – Dissertation Co-Advisor
Professor, Department of Linguistics

Marie K. Huffman - Chairperson of Defense
Associate Professor, Department of Linguistics

Jiwon Hwang
Lecturer, Asian and Asian American Studies

Yoonjung Kang
Professor, Centre for French and Linguistics,
University of Toronto Scarborough

This dissertation is accepted by the Graduate School

Charles Taber

Dean of the Graduate School

Abstract of the Dissertation

Production and Perception of English Word-final Stops by Korean Speakers

by

Jungyeon Kim

Doctor of Philosophy

in

Linguistics

Stony Brook University

2018

One puzzle in loanword adaptation involves a situation where a foreign structure is changed even when the original structure would be legal in the borrowing language. An example of this apparently unnecessary repair is the tendency to insert a vowel after a word-final stop in English borrowed words into Korean (e.g., *peak* → [$p^{h}ik^{h}$ɨ]), even when the forms would be pronounceable in Korean, since native Korean words may end in stops. The goal of this dissertation is to investigate the effects of different linguistic factors on the likelihood of vowel insertion and to determine whether this unmotivated vowel insertion derives from the misperception of English words or from a production grammar maintaining perceptual similarity between the English form and Korean pronunciation. The linguistic factors that this work examines are: (i) primary factors: stop release, stop voicing, and tenseness of pre-stop vowel, (ii) secondary factors: stop place and final stress, and (iii) other factors: morphological alternation and word size. I separate out the effects of these factors in a series of experiments designed to help in deciding between the adaptation-in-perception approach vs. the adaptation-in-production approach.

The experiments that I conducted for my study were: (i) a production task, where Korean speakers were asked to listen to English nonce words ending in a stop and to repeat what they heard; (ii) a syllable counting task, in which Korean speakers listened to English nonce words ending in a stop and indicated the number of syllables they heard in each word; (iii) a categorization task, where Korean listeners heard English nonce words ending in a stop or a stop followed by a vowel and categorized each word as consonant-final or vowel-final; and (iv) a similarity judgment task, in which Korean speakers listened to a triplet consisting of an English stop-final form and two Korean forms, one ending in a stop and one ending in stop-vowel, and indicated which of the two Korean forms the English form sounded more similar to. The results of these different tasks indicate that unnecessary vowel insertion is not a straightforward outcome that happens in adaptation but an intricate linguistic phenomenon that involves the complex interaction of perception and production.

Table of Contents

List of Figures

List of Tables

Acknowledgments

It seems unreal that I am typing this acknowledgements section, which implies that it is *really* done, though I thought at one point this would never happen. A number of people have made it possible for me to finally finish this long journey.

First and foremost, I would love to sincerely thank Ellen Broselow, one of my co-advisors. Ellen is more than just an advisor: she has been a great mentor throughout my graduate life at Stony Brook. She has been insightful, precise, and most importantly, very considerate. Without her understanding, this dissertation would have simply been impossible. Christina Bethin, my other co-advisor, has helped me on numerous occasions. I have benefited so much from her detailed comments on my thesis. I sincerely appreciate her kind and thoughtful words especially when I had a tough time preparing for my defense and revising my final draft.

I would like to thank Marie Huffman, the chairperson of my defense, for giving me many useful comments on analyses, organization, and formatting. I must say that I truly appreciate having the opportunity to sit in on her experimental phonetics class, which was extremely helpful in developing my production study. I am also very thankful to have Jiwon Hwang and Yoonjung Kang on my committee. They made valuable comments on my thesis and their suggestions have been incorporated into various parts of this dissertation.

By coming to study at Stony Brook University, I have had the honorable opportunity to know the faculty members and staff members at the Department of Linguistics, who are all excellent: Mark Aronoff, Richard Larson, Dan Finer, Bob Hoberman, John Bailyn, John Drury, José Alberto Elías-Ulloa, Francisco Ordóñez, Lori Repetti, Marianne Catalano, Jiwon Yun, Michael Becker, Thomas Graf, Sandra Brennan, and Michelle Carbone.

I would like to express my genuine gratitude to my colleagues. They have made my graduate life so memorable: Sokhun Kim, Sophia Kao, Rob Pasternak, Russell Tanenbaum, James Monette, Soyoung Lee, Yaobin Liu, Hyunah Baek, Vahideh Rasekhi, Paola Cépeda, Yunju Suh, Andrei Antonenko, Honaidah Ahyad, Alaa Melebari, Ammar Alammar, Jiyea Kim, Hongchen Wu, Chong Zhang, Chikako Takahashi, and Hwichan Oh. My thanks also go to those who help out with my experiments: Sara Catlin, Amanda Yazdani, Ellen Guigelaar, Howard Treadwell, Gianpaul Rachiele, Jamillah Rodriguez, and Chor Yan Chau.

Lastly and most importantly, I thank my mother for everything that she has done for me. I truly appreciate all the effort and sacrifice she has put into taking care of my girls. Words cannot express how appreciative I am of her and I feel tremendously lucky to have the most wonderful mother in the world. I wholeheartedly admire and respect her life, and only hope she will stay well and happy forever. I dedicate this dissertation to my outrageously supportive mother, Sumin Kwon.

Chapter 1
Introduction

When words are borrowed from one language to another, they frequently undergo adaptations to comply with the phonological structure of the recipient language (RL). However, some loanword patterns cannot easily be accounted for by the RL phonological grammar. One of those patterns involves what has been referred to as *unnecessary repair* by Peperkamp (2005), where a foreign structure is changed even when the original structure would have been legal in the RL (Golston & Yang 2001; Kang 2003; Peperkamp 2005).[1] This dissertation considers the basis of one example of apparently unnecessary repair by investigating the tendency to insert a vowel after a word-final stop in English words borrowed into Korean (e.g., *peak* → [$\mathrm{p^hik^hɨ}$]). This vowel insertion is apparently unmotivated because native Korean words may end in stops and thus English word-final stops would be pronounceable in Korean.

This dissertation considers two possible approaches to explaining this vowel insertion: adaptation-in-production vs. adaptation-in-perception. The adaptation-in-production approach generally assumes that loanword adapters store the surface form of the source language and the production grammar performs the adaptation to the native phonology (Paradis & LaCharité 1997; Jacob & Gussenhoven 2000; Steriade 2001, 2008; Yip 2002, 2006; Kang 2003; Kenstowicz 2003, 2007; Fleischhacker 2005; LaCharité & Paradis 2005; Kawahara 2006; Miao 2006; Shinohara 2006; Kang *et al.* 2008; Paradis & LaCharité 2008; Paradis & Tremblay 2009; among others). That is, the phonetic form of the original structure is faithfully taken as the abstract underlying representation and loan adaptations are then transformations produced by the phonological process in production.

To account for why even accurately perceived forms are sometimes transformed, some researchers appeal to perceptual factors and subphonemic details in explaining adaptation patterns using the production grammar (Steriade 2001; Yip 2002, 2006; Kang 2003;

---

[1] Other puzzling patterns in loanword adaptation include differential faithfulness (Davidson & Noyer 1997; Ito & Mester 2001; Broselow 2009), retreat to the unmarked (Shinohara 2000; Kenstowicz 2005; Kenstowicz & Suchato 2006), and ranking reversals (Kenstowicz 2005; Peperkamp *et al.* 2008; Broselow 2009). For a review, see Kang (2011).

Kenstowicz 2003; Fleischhacker 2005; Kawahara 2006; Miao 2006; Shinohara 2006; Kang *et al.* 2008). On the *perceptual similarity* approach, originally proposed by Steriade (2001), speakers possess knowledge of perceptual similarity (P-map) between foreign and native sounds, and perceptual factors are incorporated into grammatical constraints that can be ranked with respect to other grammatical constraints. For example, the perceptual similarity approach argues that Korean speakers insert a vowel following an English final released stop to maintain perceptual similarity between the English form and the Korean adaptation since a stop plus vowel is the perceptually closest Korean structure to the English stop release. That is, this hypothesis assumes that loan adaptation is done by sophisticated adapters who have the ability to accurately perceive foreign sounds and choose the closest native language structure by means of a P-map which exists as a component of their grammar (Steriade 2001).

An alternative approach to accounting for unnecessary vowel insertion is the adaptation-in-perception approach. This view claims that loanword adaptations take place during the perception of foreign inputs and not in the production grammar (Silverman 1992; Dupoux *et al.* 1999; Peperkamp & Dupoux 2003; Vendelin & Peperkamp 2004; Peperkamp 2005; Kabak & Idsardi 2007; Peperkamp *et al.* 2008; Boersma & Hamann 2009; Broselow 2009; Calabrese 2009; Padgett 2010; de Jong & Park 2012; Kwon 2017; among others). The adaptation-in-perception approach, like the perceptual similarity approach, argues that loanword mapping is essentially perceptually based and that acoustic details crucially play a role in perceptually matching foreign forms with native forms. However, this approach differs from the perceptual similarity approach in that the set of adaptations includes not only a mapping to native segments and tones but also a mapping to native syllables, which allows vowel insertion in perception (Peperkamp 2005; Peperkamp *et al.* 2008; Boersma & Hamann 2009). For example, Boersma & Hamann (2009) consider perception-driven adaptations with grammatical tools to be part of a perception grammar which listeners use in assigning a phonological representation to an auditory form.

While researchers take various positions on the role of perception in loanword adaptation, most generally agree that even if perception cannot account for all effects, it does play a special role. Overall, the adaptation-in-perception approach makes the powerful empirical prediction that loanword adaptation is closely connected to perception.

The present study

Korean has a three-way laryngeal contrast in stops: voiceless unaspirated, voiceless aspirated, and voiceless tense. As shown in (1), only voiceless unaspirated stops are allowed in final position, with all three categories realized as voiceless unaspirated in this position.

(1) Final stops in native Korean

a. Final unaspirated stops

/pap/	→	[pap˺]	'meal'
/kot/	→	[kot˺]	'soon'
/mok/	→	[mok˺]	'neck'

b. Neutralization in final position

/apʰ/	→	[ap˺]	'front'
/patʰ/	→	[pat˺]	'field'
/puʌkʰ/	→	[puʌk˺]	'kitchen'
/pak'/	→	[pak˺]	'outside'

Considering the fact that voiceless unaspirated stops may occur word-finally in Korean, we would expect that words borrowed from English that end in a voiceless stop would be adapted as ending in a Korean voiceless unaspirated stop, a legal Korean structure. It is therefore surprising to find that loanwords frequently depart from the English structure in two ways: the English final stop is realized as aspirated, and a vowel is inserted after the final stop, as shown in (2).

(2) Loanword phonology: Adaptation of final voiceless stops as aspirated stop plus vowel

rope	→	[lopʰɨ]
knit	→	[nitʰɨ]
peak	→	[pʰikʰɨ]

This vowel insertion is a case of unnecessary repair, which this dissertation aims to investigate. One explanation, along the lines of the perceptual similarity approach, proposed by Kang (2003) following Steriade (2001), assumes that Korean speakers accurately perceive the English forms, but they insert a vowel in their production in order to maintain perceptual similarity between the English and Korean forms. Kang focuses on two perceptual factors favoring vowel insertion after English word-final postvocalic stops: stop release and stop voicing. Release is relevant because word-final stops in Korean are never released (Huh 1965; Kim 1971; Chung 1986), while English word-final stops are variably released (Gimson 1980; Crystal & House 1988; Byrd 1992). Kang claims that because stop release in English is acoustically similar to the epenthetic vowel inserted after an English final stop in Korean, vowel insertion serves to make the Korean output of final stop-vowel perceptually close to English final released stops.

Voicing is relevant because as the examples in (3) illustrate, English final voiced stops are frequently also adapted with an inserted vowel.

(3) Loanword phonology: Adaptation of final voiced stops

tube	→	[tʰjubɨ]
pad	→	[pʰædɨ]
smog	→	[sɨmogɨ]

The only position in which voiced stops can occur in Korean is between sonorants, where voiceless unaspirated stops are allophonically voiced:

(4) Voicing alternation in Korean

a.	[pa**p**˺]	/pap/	‘meal’
	[pa**b**ɨl]	/pap-ɨl/	‘meal-ACC’
b.	[ko**t**˺]	/kot/	‘soon’
	[ko**d**iʌ]	/kot-iʌ/	‘soon after’
c.	[mo**k**˺]	/mok/	‘neck’
	[mo**g**i]	/mok-i/	‘neck-NOM’

Kang argues that insertion of a vowel after a voiced obstruent maintains perceptual similarity between the English and Korean forms by placing the voiced stop in a context in which voicing is legal in Korean.

An alternative approach to accounting for this vowel insertion, the adaptation-in-perception approach, differs from the perceptual similarity approach in that it does not assume that a vowel is inserted in the mapping from UR to SR, but instead that the vowel is already present in the L2 speakers' interpretation of the L2 surface form. The following chart shows the different mechanisms of loan adaptation in the two approaches.

(5) Mechanisms	**Adaptation-in-production**	**Adaptation-in-perception**
L2 acoustic signal	English *pea<u>k</u>* [+release]	English *pea<u>k</u>* [+release]
Listener's interpretation of L2: SR	pʰi<u>k</u>[+release]	pʰikʰɨ
Input to L1 production grammar	pʰik	pʰikʰɨ
Output of L1 production grammar	pʰikʰɨ	pʰikʰɨ

In fact, the loanword data shown in (2) and (3) is compatible with either of the two analyses since both approaches predict that Korean speakers will mispronounce an English word ending in a stop. Thus, the only way to tease the two hypotheses apart is to test whether Korean speakers actually do perceive final released stops as a stop plus vowel.

Several other factors have also been identified as increasing the likelihood of vowel insertion in coda position (Hirano 1994; Rhee & Choi 2001; Jun 2002; Kang 2003; Iverson & Lee 2006; Boersma & Hamann 2009; de Jong & Cho 2012; Kwon 2017). This dissertation examines the effects of those factors, which have been grouped into different categories depending on their characteristics. Primary factors are those which involve acoustic characteristics that can plausibly directly affect the perception of English final stops by Korean listeners. This category includes the release and voicing of the final stop and the tenseness of the vowel preceding the final stop. Secondary factors are those that contribute to the likelihood that a final stop will be released in English; these include the place of articulation of the final stop and the presence of stress in the syllable containing the final stop. Other factors include morphological alternation and phonological markedness, which are not direct perceptual factors, but where vowel insertion can make the relationship between underlying and surface representations consistent with Korean phonology or can transform English monosyllables to the more unmarked disyllabic word size.

(6) Factors contributing to vowel insertion

Groups	**Linguistic factors**
Primary factors	Stop release
	Stop voicing
	Vowel tenseness
Secondary factors	Stop place (labials vs. dorsals)
	Final stress
Other factors	Morphological alternation (t-s alternation for coronals)
	Phonological markedness (word size)

I will separate out the effects of all these factors in a series of experiments designed to decide between the adaptation-in-perception approach vs. the adaptation-in-production approach. In other words, does Korean speakers' vowel insertion derive from their perception of an illusory vowel or does it result from their desire to maintain perceptual similarity between an accurately perceived form in English and the adapted form in Korean? The different experimental tasks discussed in this dissertation will test the effects of each factor in Korean speakers' production and perception of English nonce forms.

I conducted a number of different studies to investigate production and perception by Korean speaking learners of English. First, in an L2 production experiment, Korean speakers heard English nonce forms ending in a stop and repeated what they heard. I also conducted three different perception experiments: a syllable counting task, a categorization task, and a similarity judgment task. In the syllable counting task, Korean speakers listened to English nonce words ending in a stop and indicated the number of syllables they heard in each word. This task can probe occurrence of perceptual epenthesis, assuming that syllable counting is associated with the number of vocalic segments in a stimulus and thus an indicator of perception of an illusory vowel. For instance, if a listener indicates a two-syllable response after listening to a monosyllabic stimulus ending in a released stop, it would suggest that the listener perceives two vocalic segments and the final released stop is parsed in intervocalic position between a preceding vowel and an epenthetic vowel. This experimental technique has been widely used in various studies (Lim 2003; Berent et al. 2007; Coetzee 2010; de Jong & Park 2012).

In the categorization task, Korean listeners heard English nonce words ending in a stop or a stop followed by a vowel, and categorized each word as consonant-final or vowel-final. Finally, in a similarity judgment experiment, Korean speakers heard a triplet consisting of an English stop-final form and two Korean forms, one ending in a stop and one ending in stop-vowel, and indicated which of the two Korean forms the English form sounded more similar to. This similarity judgment task is different from the other two perception tasks in that it is more directly connected to conscious judgments of perceptual similarity between native and foreign forms rather than direct perception. Also, the similarity judgment task specifically asked participants to compare English vs. Korean nonce forms and not just to hear English forms alone.

The overall results of the different experiments turned out to be somewhat mixed. The results of all three perception experiments were more compatible with the adaptation-in-perception approach than with the adaptation-in-production approach, showing that three linguistic factors—release and voicing of the final stop, and tenseness of the vowel preceding the final stop—had a significant effect in the online perception of Korean listeners. I expected to see the influence of these three factors since they involve acoustic cues that can directly affect Korean listeners' perception of C vs. CV. This result confirmed that Korean L2 speakers do interpret the foreign auditory forms according to the meaning of the acoustic cues in their native language. However, my experimental results showed that the other factors that are less directly related to perception may also play a role in loan adaptation although they did not show consistent effects. Thus, it is hard to simply conclude that unnecessary vowel insertion derives only from either misperception by Korean speakers or their accurate perception based on the knowledge of perceptual similarity. In fact, the phenomenon of unnecessary repair is not a straightforward outcome that happens in adaptation but a very complex process involving different levels of perception, processing, and production.

Chapter 2
Production Errors

The purpose of this chapter is to investigate the production of English words ending in a stop by Korean native speakers and to determine whether the speakers inserted a vowel following the English final stop. In this chapter, I report on two different studies: a survey and a production experiment. The survey analyzes the production patterns of English final stops in a corpus of Korean loanwords from English. In the production experiment, Korean and English speakers heard English nonce forms and repeated what they heard. The corpus study found that 49% of words showed vowel insertion. In contrast, the transcriptions of the Korean productions by English native speakers showed vowel insertion in only 5% of productions. However, the pronunciation of English final stops showed burst noise intervals that were significantly longer for Korean speakers than for English speakers. In the following section, I introduce the Korean sound system and phonotactics of stop consonants and the factors that have been claimed to affect the likelihood of vowel insertion.

2.1 Korean Sound System

I start with a description of the Korean sound system. As shown in the phoneme inventory below, Korean has a three-way laryngeal contrast in stops in onset position: lax, aspirated and tense.

(1) Phoneme inventory of Korean (Kang 2003: 222)

p	p^h	p’	t	t^h	t’	k	k^h	k’		i	ɨ	u
			ts	ts^h	ts’					ɛ	ə	o
			s		s’				h	æ	ɑ	
m			n			ŋ						
			L							j		w

Aspirated and tense stops do not occur in final position, where they are realized as unaspirated. As shown in the examples in (2), Korean does not allow word-final stops to be released.

(2) Final stops in Korean

a. Final unaspirated stops

/pap/	→	[pap˺]	‘meal’
/kot/	→	[kot˺]	‘soon’
/kæk/	→	[kæk˺]	‘guest’

b. Neutralization in final position[2]

/ap^{h}/	→	[ap˺]	‘front’
/pat^{h}/	→	[pat˺]	‘field’
/puʌk^{h}/	→	[puʌk˺]	‘kitchen’
/pak’/	→	[pak˺]	‘outside’

As shown in (3), Korean does not have a voicing contrast although lax stops become allophonically voiced between sonorants. Examples given in (3) show voicing alternations for each place of articulation.

(3) Voicing alternation in Korean

a.	[t^{h}o**p**˺]	/t^{h}op/	‘saw’ (noun)
	[t^{h}o**b**ɨl]	/t^{h}op-ɨl/	‘saw-ACC’
b.	[pa**t**˺]	/pat-/	‘to receive’
	[pa**d**ara]	/pat-ala/	‘Receive! (imperative)’
c.	[ya**k**˺]	/yak/	‘medicine’
	[ya**g**i]	/yak-i/	‘medicine-NOM’

Even though final stops are permitted in Korean, vowels are often inserted after final stops in words borrowed from English, even after final voiceless stops. It has been proposed that several factors influence the likelihood of vowel insertion in this position (Hirano 1994; H. Kang 1996; O. Kang 1996; Rhee & Choi 2001; Jun 2002; Y. Kang 2003). The proposed relevant factors are summarized in Table 2.1.

[2] There are no existing words ending in /p’/ or /t’/ in Korean, which are considered an accidental gap.

Table 2.1. Factors affecting possibility of vowel insertion after English final stops[3]

Factors	**Observations**	**Examples** (Appendix 1)
Vowel tenseness	Vowel insertion is more likely when the vowel preceding the final stop is tense than when it is lax.	Lax: step → sɨtʰɛp˺ Tense: state → sɨtʰɛitʰɨ
Stop voicing	Vowel insertion is more likely when the final stop is voiced than when it is voiceless.	Voiceless: plot → pʰɨllot˺ Voiced: plug → pʰɨllʌgɨ
Stop place	Vowel insertion is more likely when the final stop is coronal than when it is labial or dorsal.	Labial/dorsal: cap/bag → kʰæp˺/pæk˺ Coronal: bat → pætʰɨ
Final stress	Vowel insertion is more likely when the final syllable is stressed.	Unstressed: handbag → hændɨbæk˺ Stressed: handmade → hændɨmɛidɨ
Word size	Vowel insertion is more likely when the word is monosyllabic.	Polysyllabic: moonlight → munlait˺ Monosyllabic: light → laitʰɨ

2.2 Survey

In this section, I report on a study of vowel insertion after a word-final stop in Korean loanwords borrowed from English. I describe vowel insertion patterns in this position based on material compiled in publications of the National Academy of the Korean Language (2001; 2002; 2007a, b; 2010).[4] I first discuss the overall frequency of vowel insertion and previous proposals about which linguistic factors affect insertion. Then I discuss the frequency of each production pattern of English final stops (vowel insertion, no vowel insertion, and optional vowel insertion) in loanwords for vowel tenseness, stop voicing, stop place, word size, and final stress.[5]

The analysis of the corpus data was based on 540 Korean loanwords from English whose English source word ends in a stop, a corpus that I collected from loanword lists published by

[3] In addition to the generalizations given in Table 2.1, there exist many examples that are inconsistent with each observation (e.g., *plot* ends in a coronal stop but a vowel is not inserted, *bat* has a voiceless final stop but a vowel is inserted, and so on).
[4] Kang (2003) used a loanword list published in 1991 by the National Academy of the Korean Language where the list contained loans gathered from books published in 1990. The corpus complied for the current study is more recent since the loanwords were collected from sources published in the 2000s.
[5] Two additional factors besides these five, stop release and input channel (auditory vs. visual inputs), have been identified in the literature. According to previous proposals, vowel insertion is more likely to apply when the final stop in oral inputs is released than when it is unreleased (Hirano 1996; Rhee & Choi 2001; Y. Kang 2003), and when English words are presented in written form than when they are given in oral form (Jun 2002). However, it is not possible to analyze the contribution of these two factors in this analysis because the data consists of established loanwords gathered from books.

the National Academy of the Korean Language (2001; 2002; 2007a, b; 2010). Out of 540 English words with a final stop, 264 were consistently adapted with final vowel insertion and 214 were consistently adapted without final vowel insertion, while 62 were variably adapted both with and without vowel insertion. The frequency of each of these three patterns of vowel insertion in the corpus is displayed in Figure 2.1. The complete list of loanwords is provided in Appendix 1.

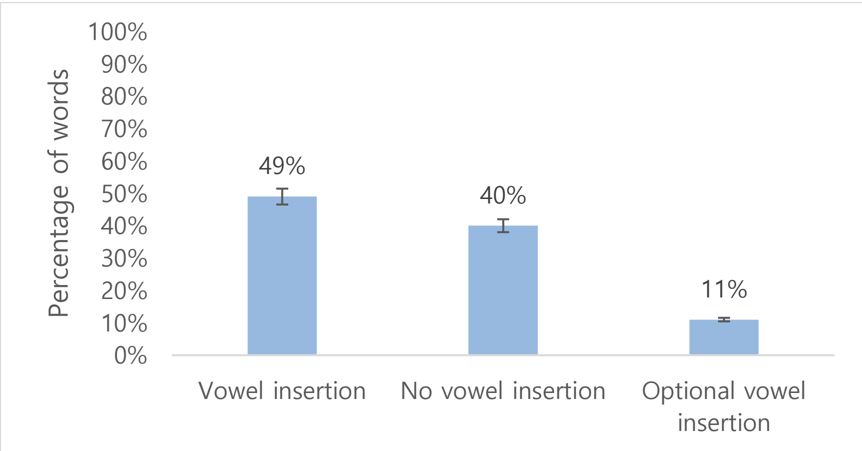

Figure 2.1. Adaptation patterns of English words ending in a stop (Error bars indicate 95% confidence intervals)

In order to determine the importance of each property, the loanword frequency was calculated using Pearson's chi-squared test in R (R Development Core Team 2016). The dependent variable was the adaptation pattern (vowel insertion, no vowel insertion, or optional vowel insertion). All the attributes of the factors were coded using treatment coding, i.e., LAX: lax = 0, tense = 1; TENSE: tense = 0, lax = 1; VOICELESS: voiceless = 0, voiced = 1; VOICED: voiced = 0, voiceless = 1; LABIAL: labial = 0, non-labial = 1; CORONAL: coronal = 0, non-coronal = 1; DORSAL: dorsal = 0, non-dorsal = 1; MONOSYLLABIC: monosyllabic = 0, polysyllabic = 1; POLYSYLLABIC: polysyllabic = 0, monosyllabic = 1; UNSTRESSED: unstressed = 0, stressed =1; STRESSED: stressed = 0, unstressed =1. Each factor turned out to be statistically significant ($p < 0.001$), which indicates that all factors affected vowel insertion after the final stop; the test statistics are summarized in Table 2.2. Figures 2.2-2.14 visually summarize the frequency of adaptation patterns for each attribute in Korean loanwords from English words ending in a stop.

Table 2.2. Pearsons' chi-square test of predictors

Predictor	χ^2	***df***	**p-value**	
Vowel tenseness	158.54	1	$p < 0.001$	***
Stop voicing	46.38	1	$p < 0.001$	***
Stop place	144.74	2	$p < 0.001$	***
Final stress	50.416	1	$p < 0.001$	***
Word size	32.71	1	$p < 0.001$	***

First, a vowel was more likely to be inserted after a word-final stop when the vowel preceding the final stop was tense than when it was lax. As summarized in Figures 2.2 and 2.3, the loanword corpus showed that VI (vowel insertion) took place in a greater percentage of words with tense pre-final vowels (89% = 176 out of 198, Figure 2.2) than in words with lax vowels (26% = 88 out of 342, Figure 2.3). The difference between words with tense pre-stop vowels vs. words with lax pre-stop vowels was significant ($\chi^2 = 158.54$, $df = 1$, $p < 0.001$).

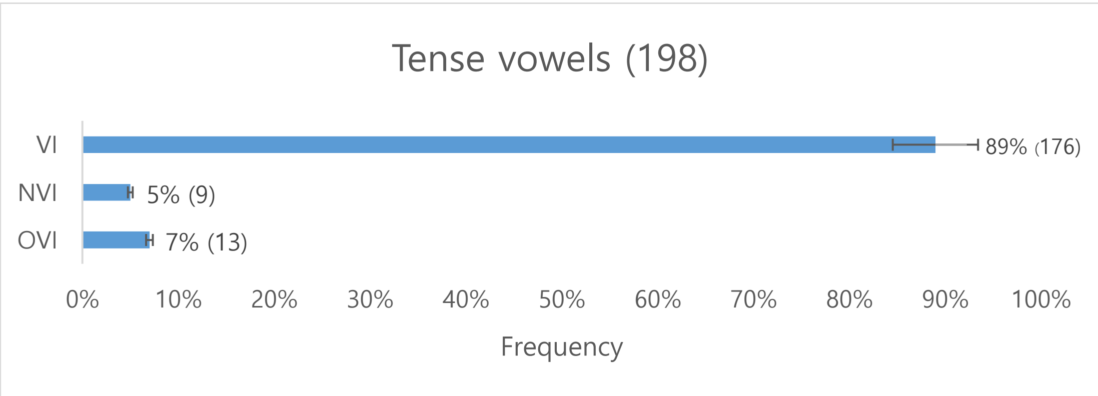

Figure 2.2. Adaptation patterns of words ending in stops with tense pre-final vowels (Error bars indicate 95% confidence intervals)

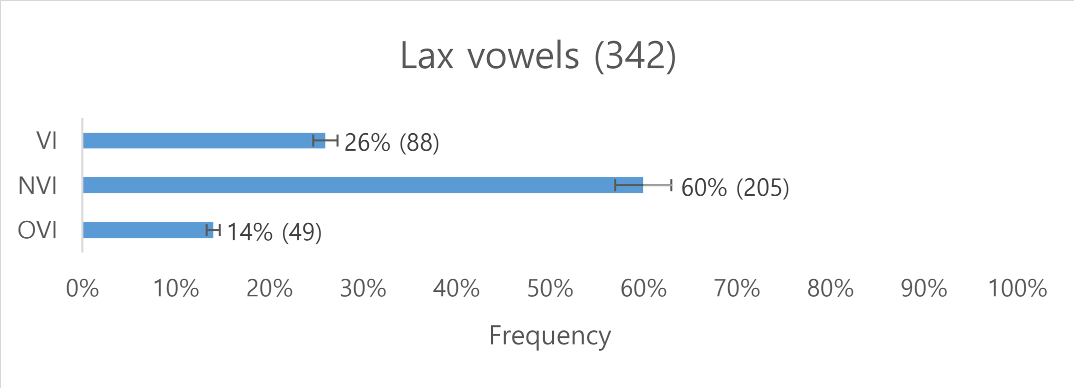

Figure 2.3. Adaptation patterns of words ending in stops with lax pre-final vowels (Error bars indicate 95% confidence intervals)

Second, vowel insertion was more likely when the final stop was voiced. As shown in Figures 2.4 and 2.5, the percentage of words with voiced final stops undergoing VI (82% = 104 out of 127, Figure 2.4) was much higher than that of words with voiceless stops (39% = 160 out of 413, Figure 2.5). The difference between words ending in voiceless stops and words ending in voiced stops was significant ($\chi^2 = 46.38$, $df = 1$, $p < 0.001$).

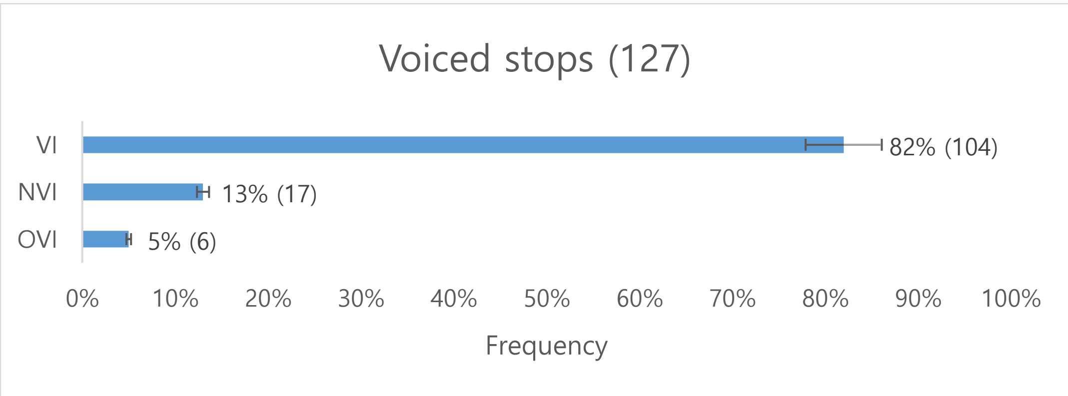

Figure 2.4. Adaptation patterns of words ending in voiced stops (Error bars indicate 95% confidence intervals)

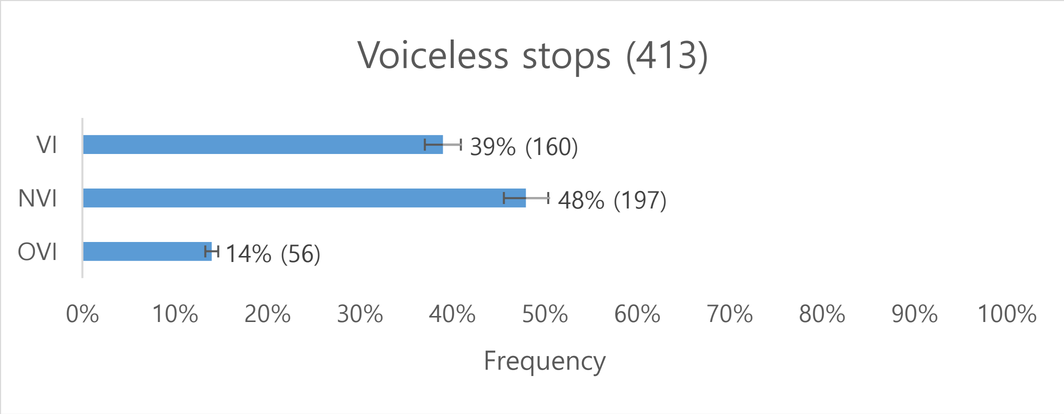

Figure 2.5. Adaptation patterns of words ending in voiceless stops (Error bars indicate 95% confidence intervals)

Third, the data in Figures 2.6 through 2.8 show that vowel insertion is more likely when the final stop is coronal than when it is dorsal, and more likely when the final stop is dorsal than when it is labial. More words with coronal final stops (68% = 200 out of 296, Figure 2.7) underwent vowel insertion than words with dorsal stops (33% = 50 out of 150, Figure 2.8), which in turn were more likely to show vowel insertion than words with labial stops (5% = 5 out of 94 in Figure 2.6). Final vowel insertion was significantly more likely when the final stop was coronal than when it was labial or dorsal (χ^2 = 144.74, *df* = 2, p < 0.001).

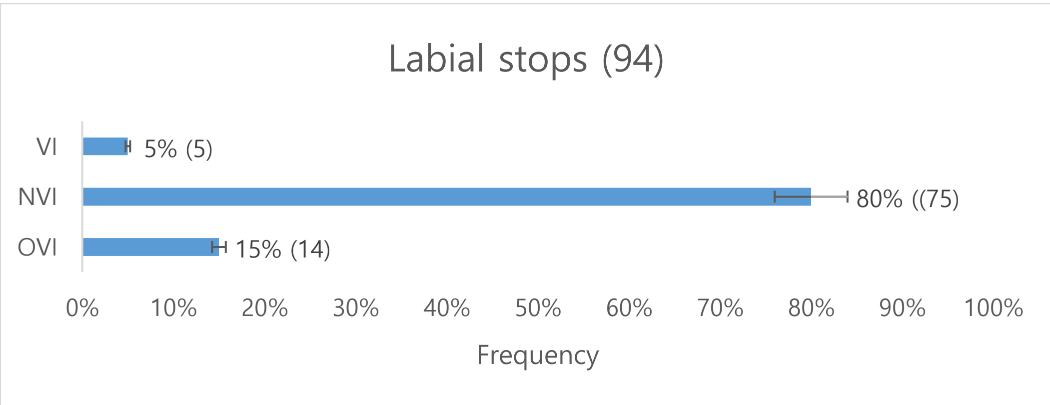

Figure 2.6. Adaptation patterns of words ending in labial stops (Error bars indicate 95% confidence intervals)

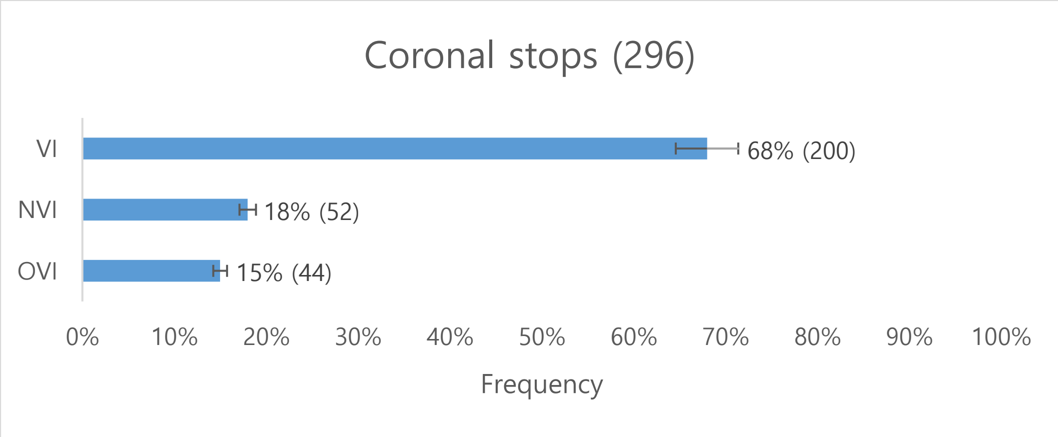

Figure 2.7. Adaptation patterns of words ending in coronal stops (Error bars indicate 95% confidence intervals)

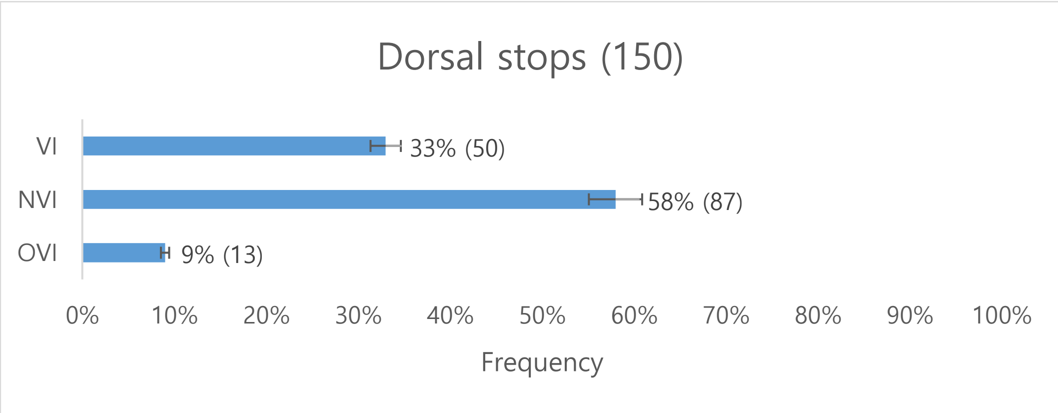

Figure 2.8. Adaptation patterns of words ending in dorsal stops (Error bars indicate 95% confidence intervals)

Fourth, Figures 2.9 and 2.10 show that vowel insertion was more likely when the final syllable was stressed than when it was unstressed. The percentage of words with stressed final syllables undergoing VI (63% = 185 out of 292, Figure 2.9) was higher than that of words with unstressed syllables (32% = 79 out of 248, Figure 2.10). The difference between words with final stress and those with no final stress was significant ($\chi^2 = 50.416$, $df = 1$, $p < 0.001$).

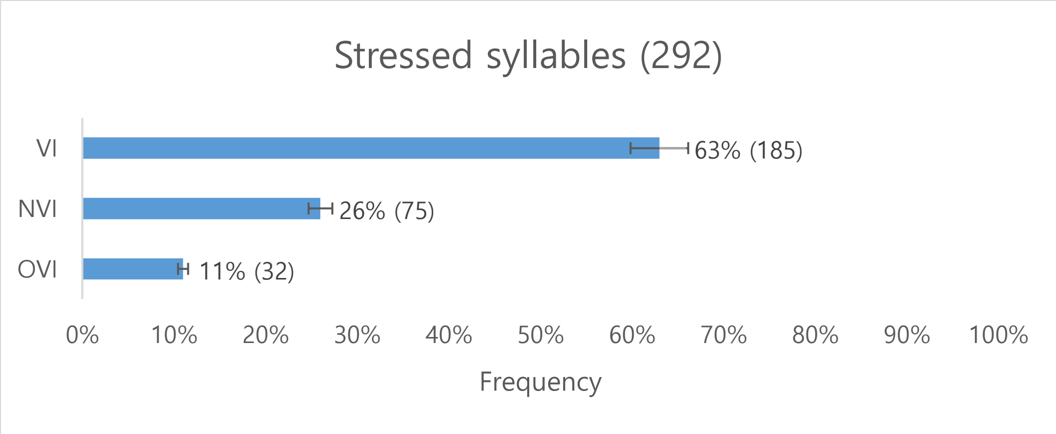

Figure 2.9. Adaptation patterns of words ending in stressed syllables (Error bars indicate 95% confidence intervals)

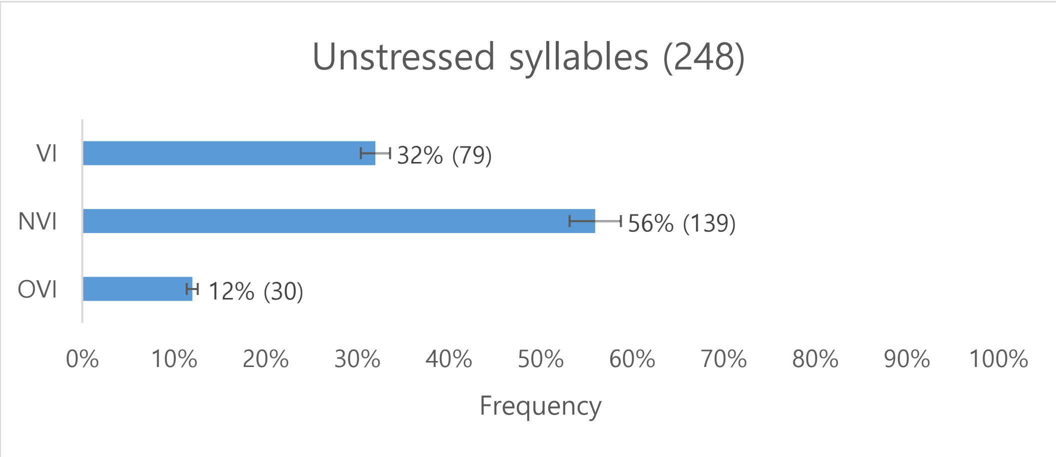

Figure 2.10. Adaptation patterns of words ending in unstressed syllables (Error bars indicate 95% confidence intervals)

In order to separate the stress effect from the effect of monosyllabicity, polysyllabic items were examined separately. Figures 2.11 and 2.12 show that the percentage of polysyllabic words with final stress undergoing VI (70% = 32 out of 46, Figure 2.11) was higher than that of words ending in unstressed syllables (32% = 79 out of 247, Figure 2.12). The difference between stressed vs. unstressed items was also significant (χ^2 = 14.593, *df* = 1, p< 0.001).

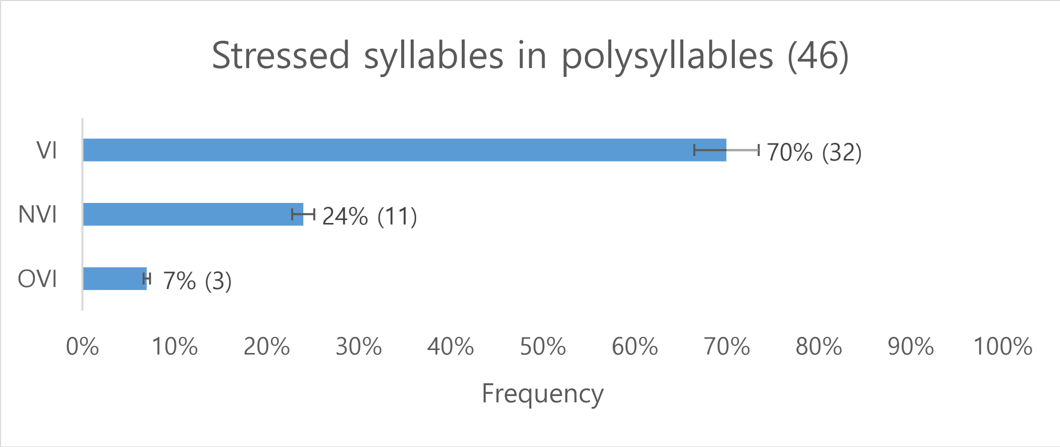

Figure 2.11. Adaptation patterns of words ending in stressed syllables in polysyllables (Error bars indicate 95% confidence intervals)

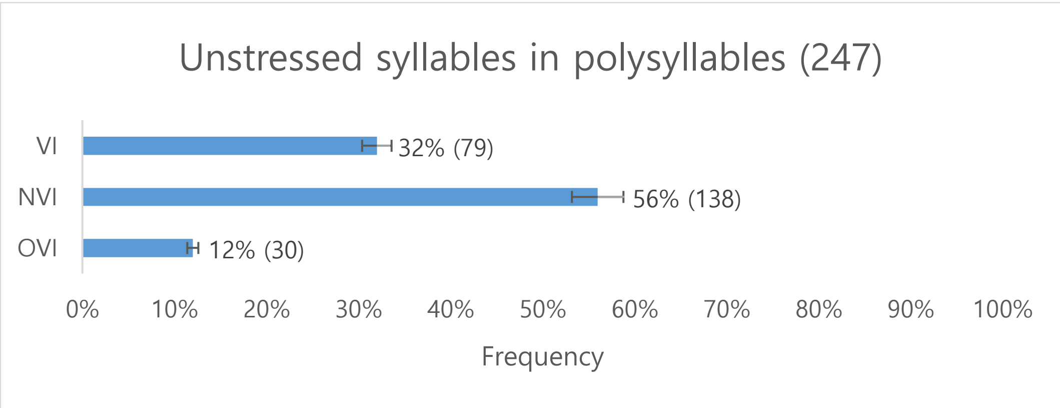

Figure 2.12. Adaptation patterns of words ending in unstressed syllables in polysyllables (Error bars indicate 95% confidence intervals)

Finally, as shown in Figures 2.13 and 2.14, the percentage of monosyllabic words undergoing VI (62% = 153 out of 247, Figure 2.13) was higher than that of polysyllabic words (38% = 111 out of 293, Figure 2.14). The difference between monosyllabic vs. polysyllabic words was significant ($\chi^2 = 32.71$, $df = 1$, $p < 0.001$).

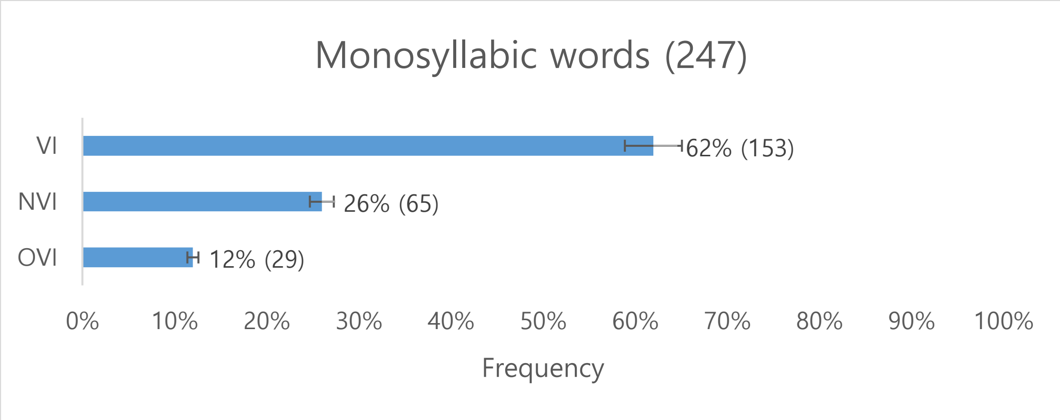

Figure 2.13. Adaptation patterns of monosyllabic words ending in stops (Error bars indicate 95% confidence intervals)

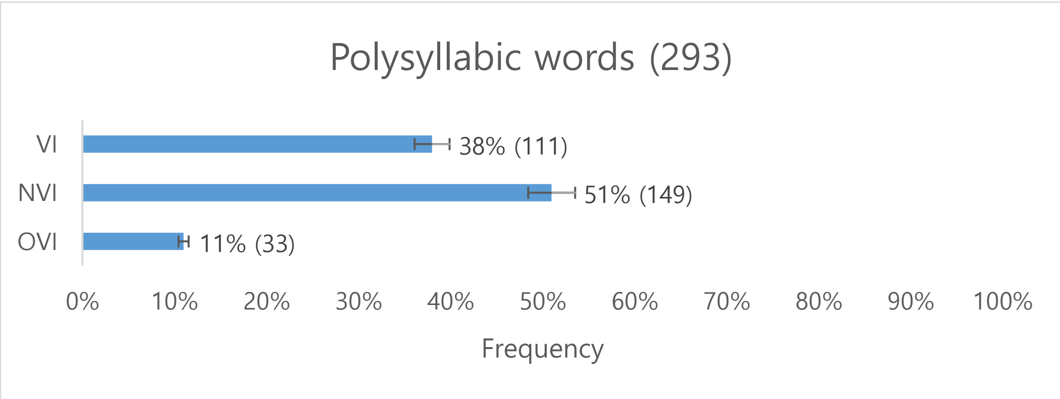

Figure 2.14. Adaptation patterns of polysyllabic words ending in stops (Error bars indicate 95% confidence intervals)

The analysis of loanword data confirms that specific phonological factors affected the likelihood of vowel insertion: vowel epenthesis was more frequent after (i) stops following a tense vowel than those following a lax vowel, (ii) voiced stops than voiceless ones, (iii) coronal stops than labial or dorsal stops, (iv) stops in stressed syllables than those in unstressed syllables, and (v) monosyllabic than polysyllabic forms. These findings are consistent with the claims of previous literature.

The survey discussed in this chapter focused on English words that have already entered the Korean lexicon. The following section will report on a production experiment which was conducted in order to compare the patterns in integrated loanwords of the corpus analysis with Korean speakers' online production of English words that are not established loanwords in Korean. In the production experiment, Korean participants listened to English nonce words ending in a stop and repeated what they heard. Because stop release can be controlled in this task, this factor was added to the five other effects tested in the production nonce task.

2.3 Production experiment: repetition

In the production experiment, Korean participants listened to English nonce words ending in a stop and repeated what they heard. English speakers were recruited for the same task. To determine whether the Korean speakers inserted a vowel after final stops, their productions will be compared to those of English speakers in terms of the duration of burst noise intervals following the closure of final stops.

2.3.1 Participants

10 Korean and 10 English native speakers participated in the experiment. The Korean participants, 5 males and 5 females (mean age: 23.9, SD: 2.0), were recruited from Sogang University in Seoul, South Korea. Their average age of first exposure to English study was 10.2 years (SD: 1.9). No participants were English majors or had lived in an English-speaking country at the time of the experiment. As a control group, 10 native speakers of American English recruited from Stony Brook University participated in the repetition experiment, 5 males and 5 females (mean age: 26.3, SD: 4.3). They were monolingual and had no experience with Korean. None of the participants reported any speech or hearing disorders. All volunteered to take part in the experiment and were paid for their participation upon completing the task.

2.3.2 Acoustic properties of auditory stimuli

Experimental items consisted of 132 English nonce forms: 84 monosyllabic, 24 disyllabic, and 24 trisyllabic forms. Monosyllabic forms consisted of 12 words with a lax pre-stop vowel [ɛ] and 72 with 6 different tense pre-stop vowels [uː iː ai ei ɔi əu]. The shape of the monosyllabic words was CVC; that of disyllabic words was $C_1V_1C_2V_2C$; and that of trisyllabic words was $C_1V_1C_2V_2C_3V_3C$. Items varied in terms of 6 different linguistic factors: i) release of final stops, i.e., 66 items with released final stops (e.g., kɛ**b**$^{\mathbf{h}}$**,** kɛ**p**$^{\mathbf{h}}$) and 66 items with unreleased final stops (e.g., kɛ**b˺**, kɛ**p˺**); ii) voicing of final stops, i.e., 66 items with voiced final stops (e.g., kɛ**bʰ**, kɛ**b**˺) and 66 items with voiceless final stops (e.g., kɛ**pʰ**, kɛ**p**˺); iii) tenseness of pre-stop vowel, i.e., 60 items with lax pre-stop vowel (e.g., k**ɛ**b˺, k**ɛ**bʰ) and 72 items with tense pre-stop vowel (e.g., v**u**ːb˺, v**u**ːbʰ)[6]; iv) place of final stops, i.e., 44 items with labial final stops (e.g., zai**b**˺, zai**b**ʰ), 44 items with coronal final stops (e.g., zai**d**˺, zai**d**ʰ), and 44 items with dorsal final stops (e.g., zai**g**˺, zai**g**ʰ); v) stress of final syllable, i.e., 108 items with final stressed syllables including 84 monosyllabic items (e.g., kɛb˺, kɛbʰ) and 24 polysyllabic items (e.g., goˈzɛb˺, goˈzɛbʰ), and 24 items with final unstressed syllable (e.g., ˈgozɛb˺, ˈgozɛbʰ); and vi) word size, i.e., 84 monosyllabic items (e.g., kɛb˺, kɛbʰ), 24 disyllabic items (e.g., gozɛb˺, gozɛbʰ), and 24 trisyllabic items (e.g., gomozɛb˺, gomozɛbʰ). The entire set of stimuli including filler items is given in Appendix 2.

To create the auditory stimuli, a female native speaker of American English produced the experimental and filler items. The speaker was a linguist who was able to carefully control release. *Praat* (Boersma & Weenink 2018) was used to check the presence and absence of release for the auditory stimuli, which will be discussed in the following section. The speaker recorded the auditory stimuli in a sound-treated booth using a Zoom H4n recorder at 44.1 kHz sampling rate (16 bits per sample) and a Shure SM57 unidirectional dynamic microphone.

[6] Tense pre-final vowels were included only in monosyllabic items; polysyllabic items contained only lax pre-final vowels; otherwise, the study would have taken too long (84 monosyllables + 168 disyllables (84 with initial stress + 84 with final stress) + 168 trisyllabls (84 with initial stress + 84 with final stress) = 420). However, the number of lax vs. tense items will be balanced in a follow-up task so that the tense vowel effect will not be confounded with the effect of word size.

All of the auditory stimuli were analyzed to make sure that they had the phonetic properties that were hypothesized to affect Korean speakers' illusory vowel perception: (i) release/non-release of the word-final stops; (ii) release duration of the final stop; (iii) vowel duration preceding the final stops; (iv) closure length of the final stops; and (v) closure voicing duration of the voiced final stops.[7] Among these acoustic features, stop release duration can be a key acoustic attribute in that releases associated with dorsal stops have been reported to be longer than post-labial or post-coronal stops on the assumption that the length of stop release tends to increase as the place of articulation moves toward the back (Crystal & House 1988; Byrd 1993). Wilson *et al.* (2014) suggests that L2 speakers are more likely to interpret this longer stop release as having an epenthetic vowel because of the phonetic similarity between a longer release and a vowel.

Regarding stop closure duration, Lisker (1957) reports that voiced stops have shorter closure duration than voiceless stops since voiced stops have a relatively longer duration of the preceding vowel, which enhances the phonetic cue of a short closure duration on the following consonant. Measurements of stop closure in the stimuli are predicted to reveal the correlation between closure durational differences and stop voicing distinction. The duration of closure voicing for voiced stops will also help confirm that there is a phonetic difference between voiced vs. voiceless stops in the auditory stimuli. Measurements were conducted using *Praat* (Boersma & Weenink 2018).

[7] Analyzing the phonetic properties of the stimuli can support both the adaptation-in-production and the adaptation-in-perception approaches discussed in the introduction. Acoustic attributes such as stop release are related to perceptual similarity of C vs. CV, but at the same time they are very much connected to the perception of an illusory vowel because the misperception hypothesis explains how speakers misperceive foreign forms on the basis of possible phonetic factors; my experimental results will show that the details of acoustic characteristics are involved in the misperception of Korean speakers.

Release/non-release

Each stimulus classified as having a final released stop contained evidence of visible release on the waveform and spectrogram, and no visible release was seen for stops classified as unreleased. Figures 2.15 and 2.16, waveform and spectrogram for the stimuli [kɛp^{h}] and [kɛp˺], are representative. All the other stimuli also show similar release or non-release, which is consistent with this classification.

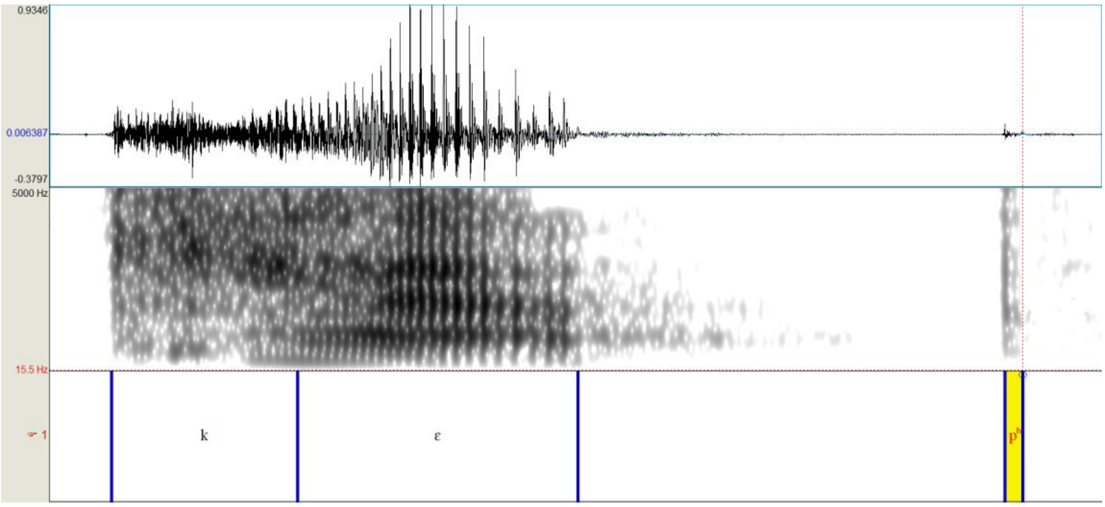

Figure 2.15. Waveform and spectrogram of [kɛp^{h}] with *released* [p^{h}]

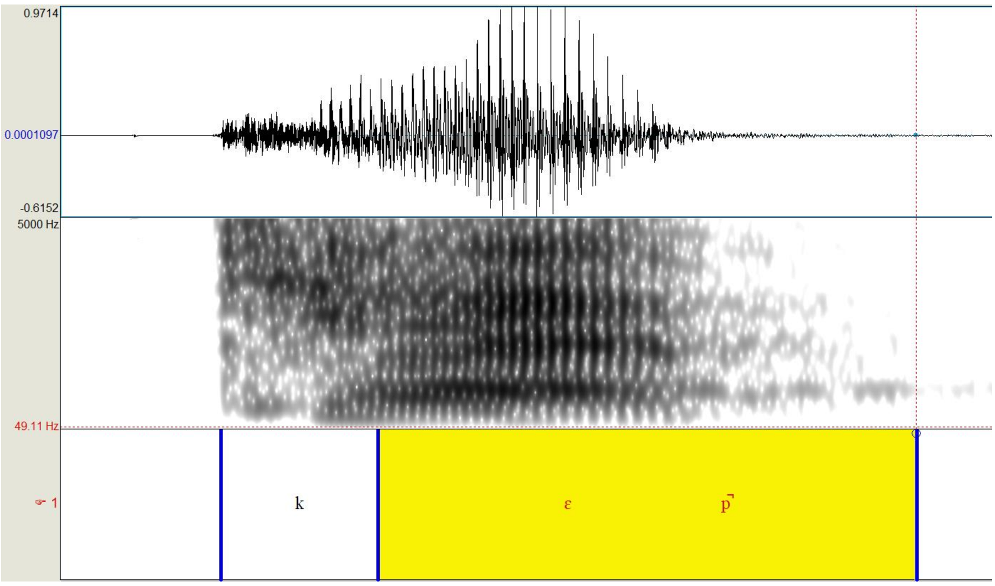

Figure 2.16. Waveform and spectrogram of [kɛp˺] with *unreleased* [p˺]

Duration of stop release

The stop release duration was measured for released final stops. The onset of stop release was defined as the point at which there was a pulse of acoustic energy for the release of the final stop. The offset of stop release was the point at which acoustic energy of the stop release significantly decreased. As shown in Table 2.3, the mean length of stop release was longer for voiceless final stops than for voiced final stops. The measurement of stop release duration was consistent with previous studies where the average duration of the release portion of voiceless stops is longer than that of voiced stops and post-dorsal releases are longer than releases associated with other place of articulation.

Table 2.3. Mean length of bursts for released final stops

m/sec	**Voiced**			**Voiceless**		
Stops	**Lab**	**Cor**	**Dor**	**Lab**	**Cor**	**Dor**
Burst length	13	20	19	13	21	28
Mean	17			21		

Vowel duration

The vowel length preceding the final stops was measured for all auditory stimuli, from the release of the preceding consonant (the point at which periodicity began to increase) to the onset of the following consonant (the point at which acoustic energy of the preceding vowel significantly decreased and there was a change in periodicity that signaled the beginning of a stop closure). The analysis involved measurement of the first two formants, F1 and F2, at the mid-point of a vowel preceding a final stop. The measurements were made manually using the Praat formant analysis algorithm. As seen in Table 2.4, vowel duration was longer before voiced stops than before voiceless stops.

Table 2.4. Mean length of vowels preceding final stops (m/sec)

Vowel length			**Voiced**			**Voiceless**			**Total mean**
Word size	**Stops**		**b**	**d**	**g**	**p**	**t**	**k**	
1 syllable	Lax vowels		157	156	179	123	116	137	145
	Tense vowels	Monophthongs	99	137	131	69	86	83	101
		Diphthongs	217	268	221	175	179	177	206
2 syllables	Lax vowels		137	197	204	116	126	130	152
3 syllables	Lax vowels		192	217	259	134	156	175	189
Mean of each segment			160	195	199	124	132	140	158
Total mean			185			132			

Stop closure duration

Stop closure duration could not be measured for unreleased stops because there was no acoustic indication of the end of the closure. The length of stop closure was measured for items ending in released stops. The onset of stop closure was defined as the point at which acoustic energy of the preceding vowel significantly decreased and there was a change in periodicity that signaled the beginning of a stop closure. The offset of stop closure was the point at which there was a burst of acoustic energy for the release of the stop closure. Duration measurements of stop closure were performed based on the waveform with reference to the spectrogram. As shown in Table 2.5, the mean closure duration of voiceless final stops was longer than that of voiced final stops. The measurement of stop closure duration confirmed that differences in stop voicing of the final consonants were cued effectively in the stimuli. The result also showed that labial stops had longer closure portions than coronal or dorsal stops, which is consistent with the findings of Zue (1976) and Byrd (1993).

Table 2.5. Closure length of released final stops

m/sec	**Voiced**			**Voiceless**		
Stop place	**Cor**	**Lab**	**Dor**	**Cor**	**Lab**	**Dor**
Closure length	147	116	105	212	164	135
Mean	123			170		

Closure Voicing duration

The stop closure voicing duration was measured for released and unreleased voiced final stops. The onset of stop voicing was the same as the stop closure onset taken as offset of the preceding vowel. The offset of stop voicing during the closure was the point at which acoustic energy and periodicity ceased. The length of voicing for released and unreleased voiced final stops is presented in Tables 2.6 and 2.8. The results for voicing duration confirmed that there was an acoustic difference between voiced and voiceless stops in the stimuli. In addition, the proportion of voicing in the closure was calculated, as shown in Table 2.7; percent closure voicing was given only for released final stops because the total length of closure of unreleased stops could not be measured.

Table 2.6. Voicing length of *released* voiced stops

(m/sec)	**Voiced**		
Stops	**b**	**d**	**g**
Voicing duration	66	42	47
Mean	52		

Table 2.7. % closure voicing of *released* voiced stops

(%)	**Voiced**		
Stops	**b**	**d**	**g**
% Voicing	45	36	45
Mean	42		

Table 2.8. Voicing length of *unreleased* voiced stops

(m/sec)	**Voiced**		
Stops	**b**	**d**	**g**
Voicing duration	50	54	56
Mean	53		

2.3.3 Procedure

Participants were directed to listen to the auditory stimuli and to repeat what they heard through a laptop computer. They were given no orthographic or other information but only aural information using a headphone. Each frame consisted of repetition of a stimulus followed by the phrase “Please repeat”. After this, participants were given three seconds to produce the stimulus. The participants were familiarized with the experimental task by taking a practice trial round with three words that were picked from the filler items. The recording of the Korean group was conducted in a sound-treated booth in the Department of English Language and Literature at Sogang University, and that of the English group in the Linguistics Department at Stony Brook University. Both recordings were done using a Shure SM57 microphone and a Zoom H4n recorder at 44.1 kHz sampling rate. This task took about half an hour to complete.

2.3.4 Predictions

The two approaches discussed in the introductory chapter, adaptation-in-production vs. adaptation-in-perception, make the same predictions for the production experiment. That is, they both predict that Korean speakers will insert a vowel after the English final stop, but for different reasons. The adaptation-in-production approach assumes that although Korean speakers accurately perceive the English final stop as a final consonant, they will insert a vowel after the stop in order to maintain perceptual similarity between English and Korean forms. On the other hand, the adaptation-in-perception approach predicts that Korean speakers will incorrectly perceive the stop as a stop followed by a vowel, and thus produce the inaccurately perceived form. Therefore, the two approaches agree that Korean speakers will produce the English final stop as a stop followed by a vowel although they disagree on how the stimuli are perceived.[8]

Producing C as CV should result in burst noise intervals following the final consonant which are longer than those associated with producing C as C even where C is released since producing C as C involves transient and frication of the stop consonant while producing C as

[8] Korean speakers' productions do not necessarily imply that they perceived a vowel; even if they accurately perceive the target L2 form, mispronunciations might result from a failure to master the correct articulation patterns (Davidson 2010). The experiments discussed in later chapters are designed to directly probe the Korean speakers’ perception of English forms.

CV possibly involves aspiration and onset of voicing following transient and frication, as will be discussed in the following section. Korean speakers are predicted to produce stronger burst noise intervals than English speakers, who never insert a vowel after the final stop and simply release the stop. The vowel that is expected to be inserted by Korean speakers is predicted to be perceived as an epenthetic vowel by English listeners. The predictions given in (4) will be tested by comparing the productions of English and Korean speakers and investigating the burst noise intervals of Korean speakers.

(4) Predictions for the production experiment

i) Korean speakers will produce significantly longer burst noise intervals after English final stops than English speakers.

ii) The longer burst noise intervals of Korean speakers will be perceived by English listeners as an epenthetic vowel.

In the following section, I will discuss the burst noise intervals following the stop closure of the final stops and check if burst noise intervals produced by Korean speakers are longer when compared to those of English speakers.

2.3.5 Burst noise intervals of final stops

The productions of 10 Korean and 10 English speakers were measured using the speech analysis software *Praat* (Boersma & Weenink 2018). For each speaker, a burst noise interval following the closure of final stops was measured. I first discuss the definition of burst noise in the description of noise events of syllable-initial prevocalic stops given in Kent & Read (2002) and then turn to "burst noise intervals" that the current study addresses. Figure 2.17 shows a spectrogram and waveform of the English word *toss* illustrating a sequence of acoustic events associated with the progression from the word-initial stop into the vowel: transient, frication, aspiration, and voicing. On the release, a pulse of energy is created as the air escapes. This plosion is called a transient because of its brevity and momentary character although this terminology is not widely used (Kent & Read 2002: 141). The transient is one of the shortest acoustic events in speech, no longer than 5 to 40ms in duration. It is followed by frication which is a turbulence noise created as the oral constriction is gradually released. Following the transient and frication we see aspiration in the case of word-initial stop consonants. Aspiration is followed by onset of voicing where vocal fold vibration for the vowel is initiated.

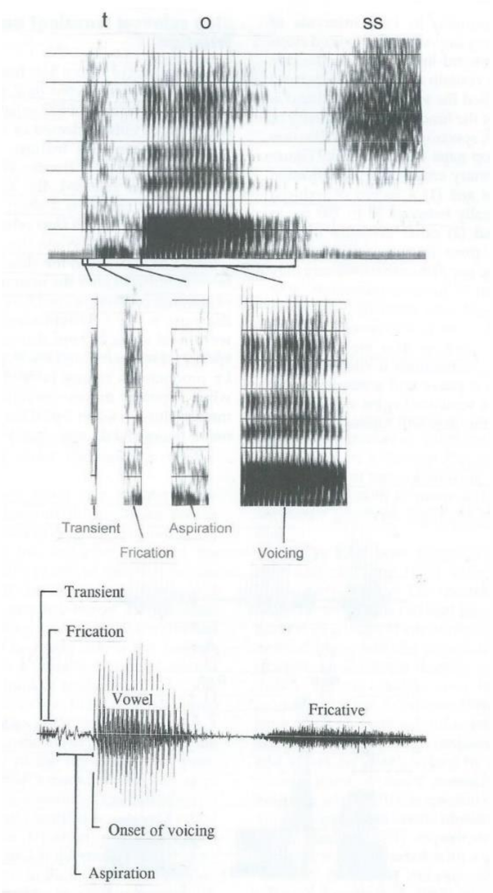

Figure 2.17. Spectrogram and waveform of the word *toss* showing acoustic events of transient, frication, aspiration, and voicing in the word-initial stop (taken from Kent & Read 2002: 143)

Unlike word-initial stop consonants, stops in word-final position, which are the focus of this dissertation, may be either released or unreleased. When the stop is not released, the closure is maintained until after the utterance is finished and no burst such as transient and frication occurs. On the other hand, when the final stop is released, transient and frication appear, as in word-initial stops. This is where we expect to see differences between the productions of English and Korean speakers. English speakers who release the final stops should produce only transient and frication; however, Korean speakers are predicted to insert a vowel following the final released stop and hence produce aspiration and voicing in addition to transient and frication. Thus, the duration of burst noise intervals after the stop closure is expected to be much longer in the productions of Korean speakers compared to those of English speakers since burst noise intervals of Korean speakers are predicted to include all of the acoustic events from transient through onset of voicing.

Measurements were conducted for items ending in released stops.[9] The onset of burst noise intervals was defined as the point at which there was a pulse of acoustic energy for the release of the final stop. The offset of burst noise intervals was the point at which frication of the final stop significantly decreased. Figures 2.18—2.21 are representative samples of how I segmented both voiced and voiceless stops produced by English and Korean speakers.

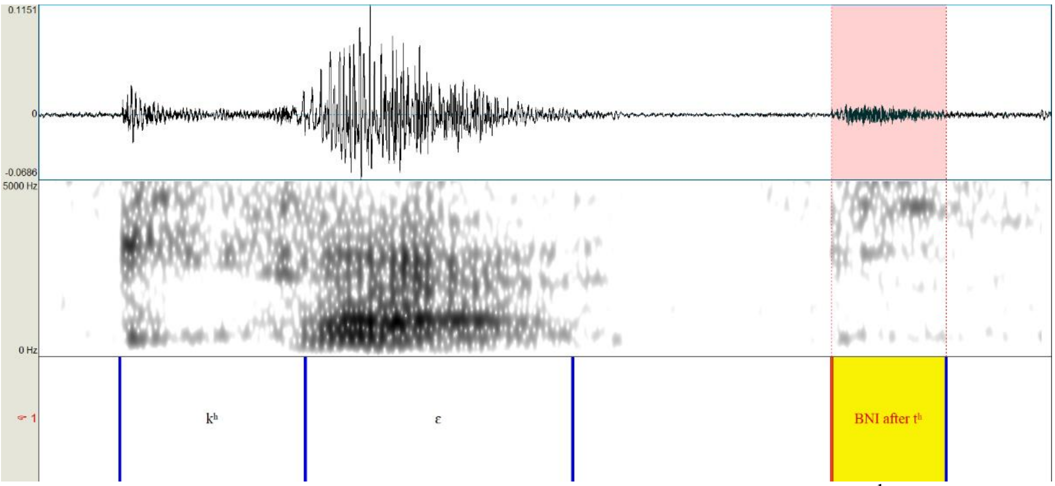

Figure 2.18. Segmentation showing BNI (burst noise interval) after [tʰ] produced by an *English* female speaker (stimulus item: [kɛtʰ])

[9] Only correct responses were included in the analysis, and error responses were excluded. Examples of incorrect responses were devoicing (b, d, g → p, t, k), voicing (p, t, k → b, d, g), and fricativization (b → v).

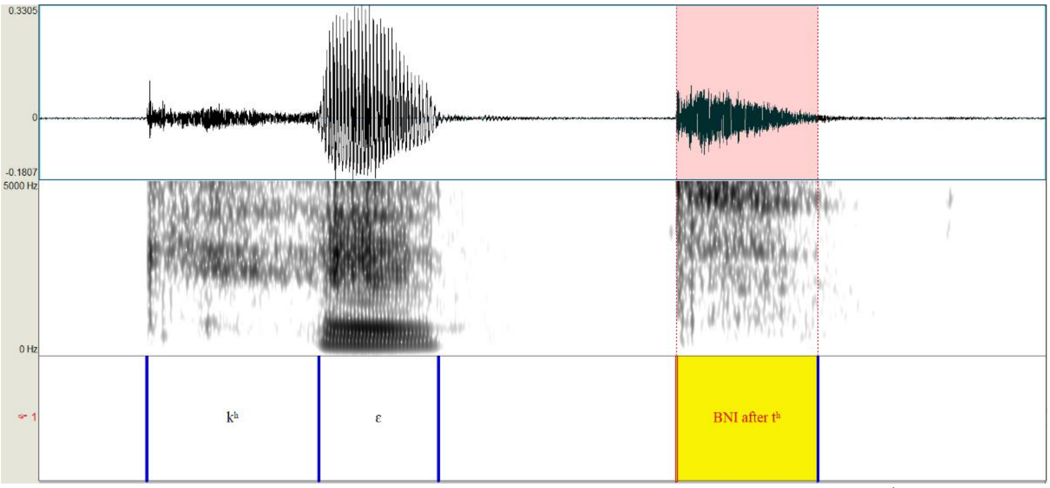

Figure 2.19. Segmentation showing BNI (burst noise interval) after [tʰ] produced by a *Korean* female speaker (stimulus item: [kɛtʰ])

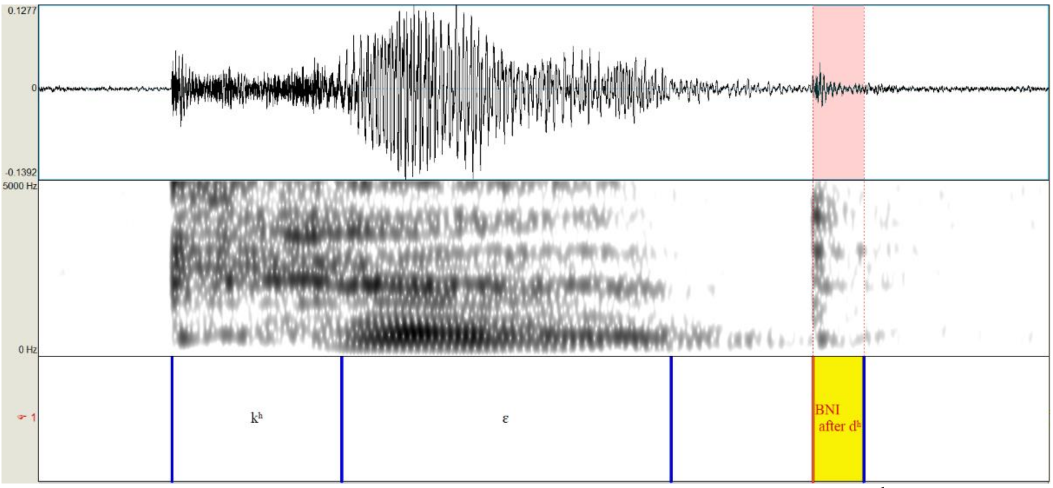

Figure 2.20. Segmentation showing BNI (burst noise interval) after [dʰ] produced by an *English* female speaker (stimulus item: [kɛdʰ])

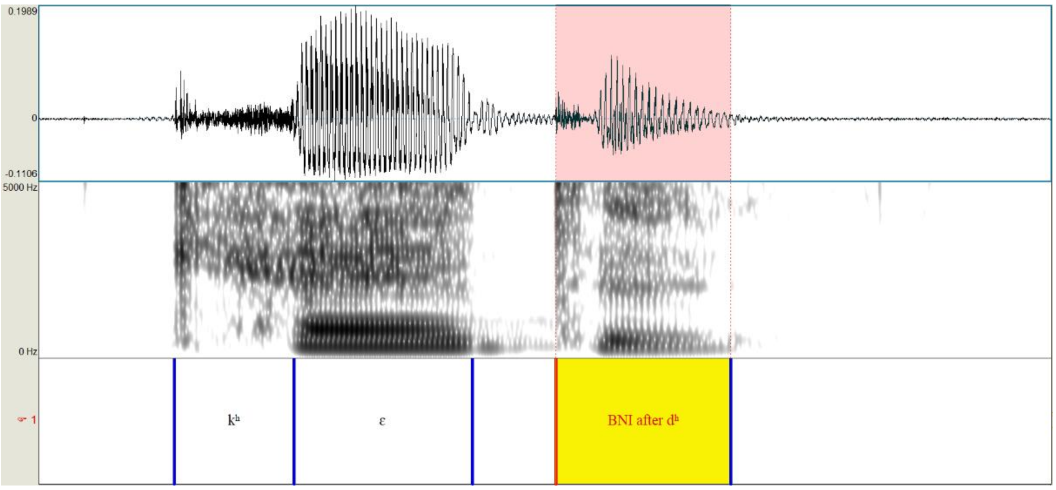

Figure 2.21. Segmentation showing BNI (burst noise interval) after [d^h] produced by a *Korean* female speaker (stimulus item: [kɛd^h])

Results

A statistical analysis was conducted using a linear mixed-effects model (Baayen et al. 2008), which examines the difference in burst noise intervals between Korean and English groups. The analysis was carried out using the *lmer* function in the *lme4* package (Bates et al. 2012) for R (R Development Core Team 2013). The dependent variable was the duration of burst noise intervals following the final stops. A fixed effect predictor was Group (Korean or English) and it was coded using deviation coding (English = -0.5; Korean = 0.5). Random effects include participants and items. Random intercept model converged and only a random intercept was included for both participants and items.

The statistical model confirmed that Korean participants had significantly longer burst noise intervals than English participants ($\beta = 0.133$, $SE = 0.004$, $t = 27.65$, $p < 0.001$), which was consistent with the prediction about differences in burst noise intervals after stop closure of final stops between the two speaker groups. As shown in Table 2.9, the mean duration of burst noise intervals for English speakers was 55ms, while that of Korean speakers was 191ms. Male speakers produced longer burst noise intervals than female speakers in both Korean and English participant groups.

Table 2.9. Mean duration of burst noise intervals produced by English & Korean speakers

Group	Gender	Participant	Mean duration (ms)
English	Female	S1	88
		S2	34
		S3	38
		S4	40
		S5	48
		F. mean	50
	Male	S6	54
		S7	34
		S8	62
		S9	65
		S10	82
		M. mean	59
	Total mean		55 (SD: 19.5)
Korean	Female	S1	213
		S2	172
		S3	135
		S4	179
		S5	169
		F. mean	174
	Male	S6	208
		S7	191
		S8	174
		S9	163
		S10	310
		M. mean	209
	Total mean		191 (SD: 47.3)

We now turn to the next question: is this longer burst noise interval of Korean speakers heard as an epenthetic vowel by English listeners? This question is important in deciding whether the Korean speakers were producing final released stops or whether they were actually inserting a vowel after the final stop. In the following section, I will discuss how English speakers transcribed the Koreans' productions to determine whether English speakers actually perceive productions of Korean speakers as having an epenthetic vowel.

2.3.6 Epenthetic vowels

In order to see if the stronger burst noise intervals found in Korean speakers' productions were heard as epenthetic vowels by English listeners, the Korean speakers' productions were transcribed by two phonetically trained native English speakers. Transcribers were asked to decide whether the Korean participants were producing a vowel word-finally or whether they were just releasing the word-final stop. Forms on which the two transcribers did not agree were transcribed by a third transcriber. The results of the transcriptions showed that only 5% of total correct productions were heard as an epenthetic vowel, i.e., 32 responses out of 648 were perceived as having a final vowel. Here, correct productions refer to the productions that were perceived as consonant-final. When participants incorrectly produced the final consonant, i.e., voiced segments as voiceless, voiceless as voiced, or stops as fricatives, these error responses were excluded from the analysis.[10]

Table 2.10 gives the numbers of tokens perceived as having an epenthetic vowel for each Korean participant and Figure 2.22 gives the percent of tokens perceived as CV. As shown in the figure, even the highest CV rate (S6) was only 19%, and 3 participants (S3, S4, & S7) had no final vowel transcribed in any of their productions (CV=0%). Although the CV rate of male speakers was over twice as high as that of female speakers, the mean rate for male speakers was still below 10%.

[10] As in the waveform analysis of burst noise intervals, only correct responses were included in the transcriptions. Total correct production samples of 10 Korean participants were 648 out of 1320 (132 stimuli × 10 participants), where they heard 660 items ending in released stops.

Table 2.10. Number of tokens perceived as final vowel (CV) vs. no final vowel (C) for each Korean participant

Gender	Participant	CV	C	Total
Female	S1	2	65	67
	S2	1	72	73
	S3	0	75	75
	S4	0	75	63
	S5	7	66	73
Female total		10	341	351
Male	S6	11	48	59
	S7	0	52	52
	S8	8	53	61
	S9	1	61	62
	S10	2	61	63
Male total		22	275	297

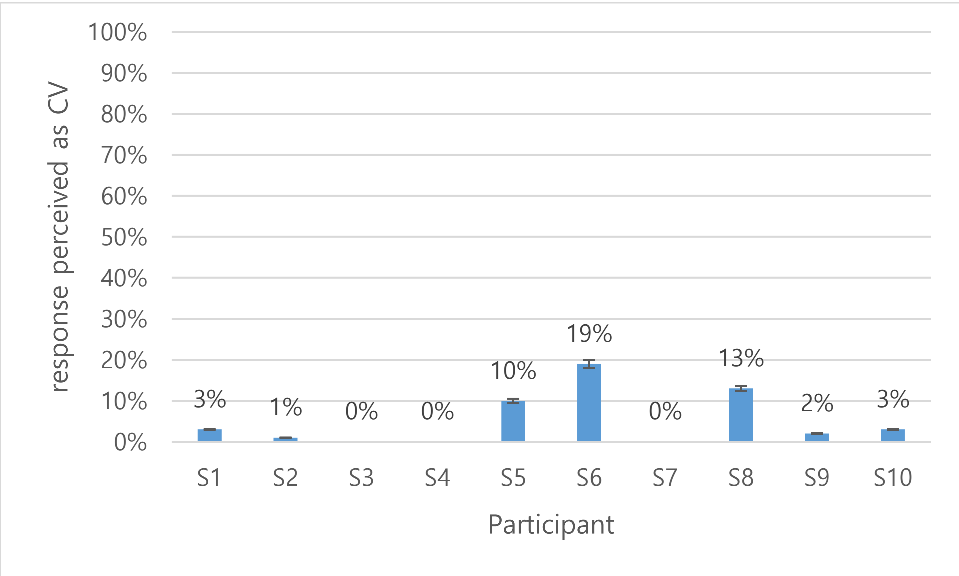

Figure 2.22. Percent of tokens perceived as final vowel (CV) for each Korean participant (Error bars indicate 95% confidence intervals)

While the first prediction for the production task was confirmed—Korean speakers produced significantly longer burst noise intervals after English final stops than English speakers—on the other hand, the second prediction was not confirmed: the longer burst noise intervals of Korean participants were not perceived by English listeners as an epenthetic vowel.

2.4 Discussion

The fact that more than 90% of Korean participants' productions were perceived to include no epenthetic vowel was not consistent with the loanword data, where vowel insertion was more frequent than lack of insertion (49% vs. 40%, Figure 2.1). The result of the production task was also inconsistent with the predictions of the adaptation-in-perception approach, because according to this view, Korean participants should have inaccurately produced the forms ending in a released stop with a vowel if they had inaccurately perceived them as ending in a vowel. Would these results be compatible with the adaptation-in-production approach? This is not simple to answer: the adaptation-in-production approach assumes that if Korean speakers correctly perceived an English final released stop as a final consonant, they should insert a vowel to make the English sound more similar to the Korean sound. The two approaches both agree that Korean participants should incorrectly produce the English final stop by inserting a vowel after the stop although they disagree on the reason for that insertion.

The difference in the results between the loan analysis and the production task might have arisen from the fact that the corpus study was based on written integrated loanwords. Korean loans written in books tend to observe the guidelines of the Korean Academy, where vowel insertion is required when certain conditions are satisfied.[11] However, in the production experiment, Korean participants were asked to immediately repeat a series of English nonce words. The results from the online adaptation would indicate that speakers were trying to imitate the release of the English final stop in an exaggerated manner by the longer burst noise after the stop.[12] The longer burst noise interval did not turn out to be identified as an epenthetic vowel by English listeners. That is, the productions of Korean participants as perceived by English speakers almost never included final vowel insertion, and the linguistic factors that have been claimed to affect vowel epenthesis did not play a role in the productions of Korean

[11] The following is part of the guidelines: i) A word-final voiced stop shall be written with [ɨ], and ii) A word-final voiceless stop after a lax vowel shall be written as a coda, and one after a tense vowel shall be followed by [ɨ] (http://www.korean.go.kr/).

[12] It could be possible that the participants were just treating the production task as imitating a series of sounds rather than producing linguistic forms. That is, they could have been doing the task on a purely phonetic level rather than a phonological level even if they possibly still were using standards of Korean phonetics making it part of their linguistic knowledge. In that case, this would be independent of their phonological system, which is a perennial issue in experimentation.

speakers. Therefore, the results of the production task were not predicted by either of the two approaches.

There are other possible explanations for this unexpected finding. First, it is possible that Korean speakers did intend to produce a final vowel, but that English listeners failed to hear this vowel because Korean high vowels tend to be devoiced after aspirated stops (Jun & Beckman 1994). Thus, English listeners might have perceived the Korean devoiced vowel as consonant release. It is also possible that the nature of the task was simply too different from actual loan adaptation, where listeners might have more competing demands on their attention. Here in the production task, participants heard and repeated a single word, whereas in loanword adaptation listeners might hear different words in different contexts while they are doing real processing and therefore be more likely to misperceive.

The mismatch between the loanword patterns and the production experiment raises the question of what happens in perception of English forms by Korean speakers. Do Korean listeners accurately perceive an English final released stop as a final consonant, as the adaptation-in-production approach predicts, or do they misperceive it as a stop followed by a vowel, as the adaptation-in-perception approach predicts? The following chapters will report on three different perception experiments designed to answer this question.

Chapter 3
Syllable Counting

As discussed in Chapter 2, the participants in the production study rarely inserted a vowel after English word-final stops, which was surprising given the frequency of vowel insertion in the loanword data. The lack of vowel insertion in the production data was not predicted by either of the two approaches introduced in Chapter 1, which suggests the need for a better test of whether Korean speakers correctly perceive English words ending in stop as consonant-final. In this chapter, I report on a syllable counting experiment designed to determine whether speakers accurately perceive English words ending in a stop and whether this perception is affected by specific linguistic factors. The results of the experiment provide evidence that Korean listeners often do hear an extra syllable in words ending in a stop, supporting the adaptation-in-perception view that unnecessary vowel epenthesis results from the misperception of English words rather than from a production grammar maintaining perceptual similarity between the English form and Korean pronunciation. The structure of this chapter is as follows: Section 3.1 outlines the hypotheses concerning the role of perception in vowel insertion, and Section 3.2 reports on the syllable counting experiment designed to investigate the effects of linguistic factors identified as contributing to vowel insertion.

3.1 Hypotheses

As discussed in the introductory chapter, Kang (2003) argues that vowel insertion after English final stops is driven by the desire to maintain perceptual similarity between the English form and the Korean adaptation because a sequence of stop followed by epenthetic vowel is the perceptually closest Korean structure to an English final released or voiced stop.[13] In addition to the two factors of release and voicing, Kang discusses additional factors that affect the likelihood that an English final stop will be released, among them the effect of preceding

[13] Kang clearly mentions that voicing does not correlate with release; instead, she specifically states that a vowel is added to maintain voicing of the final stop since voiced stops in Korean can only occur before a vowel (Kang 2003: 244).

tense and lax vowels and the place of articulation of the final stop. In the TIMIT corpus of American English, 58% of final stops following a tense vowel are released, but only 41% of final stops following a lax vowel are released (Kang 2003: 241).[14] This difference is reflected in the Korean loanword vowel insertion pattern, with more epenthesis when the pre-final vowel is tense (89%) than when it is lax (28%) (Kang 2003: 232). Kang finds that the place of the final stop also affects the frequency of vowel insertion in Korean loanwords borrowed from English as well as the frequency of release by English speakers. The greater frequency of insertion after dorsal than labial stops in loanwords is consistent with her finding that in the TIMIT corpus, English final dorsal stops had a release frequency of 83% but labial stops had a release frequency of only 51% (Kang 2003: 250). Thus, the corpus results support her claim that the more likely a final stop is to be released by English speakers, the more likely it is to undergo vowel insertion by Korean speakers.

However, although Kang's claim concerning the relationship between release and vowel insertion was supported in the case of dorsal vs. labial stops, it was not supported for coronal stops. Even though the frequency of vowel insertion in loanwords was highest for coronals (72%), final coronal stops in the TIMIT corpus were the least likely to be released (37%) (Kang 2003: 232; 250). Kang claims that the surprisingly high frequency of vowel insertion after coronal stops arises from a factor that is not related to release: the fact that in Korean surface forms, final [t] in nouns is generally derived from underlying /s/, which is neutralized to [t] in final position, but which surfaces as [s] before vowel-initial suffixes. Kang proposes that vowel insertion after English final [t] in nouns protects the form from undergoing the normal [t-s] alternation.

In addition to the factors discussed by Kang (2003), other researchers have identified two other factors that affect the likelihood of vowel insertion by Korean speakers adapting English words: word size and final stress. Rhee & Choi (2001: 157) found that vowel insertion is more likely in monosyllabic than in polysyllabic borrowed words in their loanword corpus (1 syllable 64%, 2 syllables 34%, 3 syllables 33%, 4-5 syllables 29%). This finding agrees with the vowel insertion pattern in Kang's loanword list, where the frequency of final vowel insertion for

[14] Kang (2003) conducted a survey of the TIMIT corpus to examine the release pattern of postvocalic word-final stops. The TIMIT corpus contained recordings of 2342 different sentences read by 630 speakers from 8 major dialects of American English, resulting in a total of 6300 sentences (Grofolo, Lamel, Fisher, Fiscus, Pallett, Dahlgren & Zue 1993).

monosyllabic words is higher than that for polysyllabic words (68% vs. 36%, Kang 2003: 227).[15] However, although Kang mentions the possibility that the word length effect can be accounted for by the asymmetry in stop release frequencies of English, she does not investigate this word length effect. In addition, in an experiment where Korean participants heard auditory stimuli and wrote what they heard on a response sheet, Jun (2002) found that vowel insertion was more likely when the final syllable was stressed (55%) than when it was unstressed (52%).[16] This finding is also consistent with Kang's loanword list, where the frequency of vowel insertion in polysyllabic words with final postvocalic stops was higher when the final syllable was stressed than when it was unstressed (51% vs. 14%, Kang 2003: 227).[17]

The syllable counting task discussed in this chapter is designed to test whether Korean speakers' vowel insertion derives from their perception of an illusory vowel or from their desire to maintain perceptual similarity between an accurately perceived final consonant in English and the adapted form in Korean. Based on the findings of Kang (2003) and many others (H. Kang 1996; O. Kang 1996; Rhee & Choi 2001; Jun 2002), the experiment was devised to investigate the effects of each factor identified as contributing to vowel insertion. As indicated in Chapter 1, the factors are grouped into different categories depending on their characteristics, as shown in (1) below. Primary factors, which make a form containing a final stop acoustically similar to a Korean form ending in a stop plus vowel, are stop release, stop voicing and vowel tenseness. Stop release and stop voicing are argued by Kang (2003) to directly affect the likelihood of vowel insertion, either because release creates a structure that is acoustically similar to the epenthetic vowel or because voicing can only occur prevocalically in Korean. Vowel tenseness also belongs to the primary factors because it is argued that a vowel is longer in an open syllable than in a closed syllable in Korean (Han 1964; Koo 1998; Chung & Huckvale 2001), which could lead to the tendency to insert a final vowel after a form with a

---

[15] Kang's (2003) study was based on a loanword list compiled by the National Academy of the Korean Language. The list contains loans from about 5000 English words and phrases gathered from newspapers and magazines published in Korea in 1990.

[16] Although Jun (2002) indicates that there was a significant difference ($p < 0.01$) between stressed and unstressed items in her study, the t-test that she employed for her work is generally used for specific kinds of work such as corpus work and experiments with only one participant (Johnson 2008; Gries 2013). In her experiment, nonce words were used and 260 participants participated. The marginal difference between stressed and unstressed items (55% vs. 52%) in her study might not have been significant if a regression model were used instead.

[17] Here, the frequency was calculated on the number of vowel insertion for words of one category (stressed vs. unstressed) out of the total number of vowel insertion for that category.

tense vowel to create an open syllable before the word-final consonant.

(1) Factors contributing to vowel insertion

Groups	Linguistic factors
Primary factors	Stop release
	Stop voicing
	Vowel tenseness
Secondary factors	Final stress
	Stop place (labials vs. dorsals)
Other factors	Morphological alternation (t-s alternation for coronals)
	Word size (preference for disyllables)

Secondary factors are stop place and final stress, which are argued by Kang (2003) to correlate with vowel insertion not because they contribute to the perceptual similarity between final C and final CV but instead because they increase the likelihood that Korean adapters will have heard pronunciations with a final released consonant. That is, for Kang, the reason the secondary factors are associated with vowel epenthesis is dependent on their effect on the likelihood of release in English pronunciations. For example, since English speakers are more likely to release a dorsal final stop, Korean speakers are more likely to hear released dorsal final stops and therefore more likely to insert a vowel in this context.

Other factors include morphological alternation and phonological markedness, where vowel insertion may make the relationship between UR and SR consistent with Korean phonology or may transform English monosyllables to the less marked disyllabic word size. The stimuli in the syllable counting task separate all of these factors, allowing us to compare across all combinations of primary, secondary and other factors to examine the effects of each one.

We have two possible explanations for the seemingly unmotivated vowel epenthesis by Korean speakers: adaptation in production vs. adaptation in perception. Recall that these two approaches make different predictions concerning Korean speakers' perception of English forms containing word-final stops. The adaptation-in-production approach predicts that when Korean speakers hear an English word with a final stop, they will accurately perceive the stop as word-final. The expectation then is that they will correctly identify a monosyllabic word as monosyllabic, a disyllabic word as disyllabic, and a trisyllabic word as trisyllabic. This approach assumes that the reason that Koreans insert a vowel after final released or final voiced stops but not after final unreleased or voiceless stops is because they consider a stop followed by a vowel to be the perceptually closest legal Korean structure to a final released or a final voiced stop.

However, the adaptation-in-perception approach makes different predictions. Under this approach, the insertion of a vowel after a final English stop reflects the tendency to hear these stops not as word-final but as followed by a vowel. The syllable counting experiment is designed specifically to test for the perception of an illusory vowel. Thus, the adaptation-in-perception approach predicts that only the primary factors which are known to contribute to perception of an illusory vowel will lead to perception of an extra syllable: an English final stop will be more likely to be perceived as followed by an illusory vowel when the stop is released or voiced or when it is preceded by a tense vowel than when it is unreleased or voiceless or when it is preceded by a lax vowel.

3.2 Syllable counting experiment

3.2.1 Participants

Thirty native speakers of Korean, who were born and raised in South Korea, participated in the syllable counting experiment. 18 participants were female and 12 were male (mean age: 25.7, SD: 11.7). Consistent with the compulsory nature of English education in modern South Korea, participants generally reported extensive study of English since early adolescence (beginning at a mean age of 11.7, SD: 2.0). Participants were recruited from Sogang University in Seoul, South Korea. No participants were English majors or had lived in an English-speaking country at the time of the experiment. None reported any history of hearing, speech, or language impairments. All gave informed consent and were paid for their participation.

3.2.2 Stimuli

The stimuli used in the syllable counting experiment are the same as the ones used in the production experiment discussed in Section 2.3.2. The entire set of stimuli including filler items is given in Appendix 2.

3.2.3 Procedure

The Korean participants were directed to listen to a randomized set of stimuli and to indicate the number of syllables in each word. They were given only auditory information through a laptop computer in a sound-treated booth. Before the start of the experiment, the definition of a syllable was explained, although most of the participants indicated that they were familiar with this concept.[18] Participants then did three practice trials selected from the fillers. After hearing each stimulus, participants wrote the number of syllables they heard on a response sheet. Listeners heard each stimulus only once and could not go back to listen again. The randomized order was the same for all speakers, and it was an open-choice experiment. This task took about 20 minutes to complete, and participants were paid for their participation.[19]

3.2.4 Predictions

Recall that the two alternatives, adaptation-in-production vs. adaptation-in-perception, do not predict exactly the same thing. They both predict that stop place, final stress, and morphological alternations should not affect the perception of syllable count. However, they make conflicting predictions about stop release, stop voicing, vowel tenseness, and word size, as shown in Tables 3.1 and 3.2. Table 3.1 shows the predictions of the adaptation-in-production approach, which predicts that Korean listeners' perception of the number of syllables in the

[18] The definition of a syllable with several examples was explained to participants: a unit of pronunciation having one vowel sound, with or without surrounding consonants, forming the whole or a part of a word.
[19] The syllable counting was the earliest task among the three behavioral experiments. The other tasks will be discussed in the following chapters. The syllable counting task was conducted in July 2014, the similarity judgement task was carried out in July 2016, and the categorization task in September 2016. Each experiment had different participants.

English forms should not be affected by the release or voicing of the final stop or the tenseness of the pre-stop vowel, even though these factors affect the acoustic similarity to Korean final C vs. CV.

Table 3.1. Predictions of the adaptation-in-production approach for syllable counting task

Linguistic factors		**Hypotheses**
Primary factors	Stop release	There will be no significant difference in the syllable counting between an English word ending in a released stop and an English word ending in an unreleased stop.
	Stop voicing	There will be no significant difference in the syllable counting between an English word ending in a voiced stop and an English word ending in a voiceless stop.
	Vowel tenseness	There will be no significant difference in the syllable counting between an English word with tense pre-final vowel and an English word with lax pre-final vowel.
Secondary factors	Final stress	There will be no significant difference in the syllable counting between an English word with a stressed final syllable and a word with an unstressed final syllable.
	Stop place (labials vs. dorsals)	There will be no significant difference in the syllable counting between an English word ending in a labial stop and an English word ending in a dorsal stop.
Other factors	Morphological alternation (coronals)	There will be no significant difference in the syllable counting between an English word ending in a coronal stop and an English word ending in a labial or dorsal stop.
	Word size (phonological markedness)	There will be no significant difference in the syllable counting between an English monosyllabic word and an English polysyllabic word.

Table 3.2 gives the specific predictions of the adaptation-in-perception approach for the syllable counting experiment depending on each linguistic factor. This hypothesis predicts that acoustic factors that make a final English stop more similar to Korean CV will cause Korean listeners to overcount the number of syllables in forms ending in released or voiced stops and also in forms in which the final stop is preceded by a tense vowel. This approach predicts that secondary factors will not have an effect on syllable counting.

Table 3.2. Predictions of the adaptation-in-perception approach for syllable counting task

Linguistic factors		Hypotheses
Primary factors	Stop release	Korean speakers will be more likely to hear an illusory vowel when the English final stop is released than when it is unreleased.
	Stop voicing	Korean speakers will be more likely to hear an illusory vowel when the English final stop is voiced than when it is voiceless.
	Vowel tenseness	Korean speakers will be more likely to hear an illusory vowel when the English pre-final vowel is tense than when it is lax.
Secondary factors	Final stress	There will be no significant difference in the perception of an illusory vowel between an English word with a stressed final syllable and a word with an unstressed final syllable.
	Stop place (labials vs. dorsals)	There will be no significant difference in the perception of an illusory vowel between an English word ending in a labial stop and a word ending in a dorsal stop.
Other factors	Morphological alternation (coronals)	There will be no significant difference in the perception of an illusory vowel between an English word ending in a coronal stop and a word ending in a labial or dorsal stop.
	Word size (phonological markedness)	Korean speakers will be more likely to hear an illusory vowel when the English word is monosyllabic than when it is polysyllabic.[20]

The next section reports on the results of the syllable counting task. I examine which hypothesis is more compatible with the results, in light of the predictions given in Tables 3.1 and 3.2. I first discuss the overall accuracy of syllable counting and then the statistical analysis of main effects as well as the interaction between factors.

[20] Here, word size is predicted to cause the illusory vowel perception, but I acknowledge that word size would not exhibit the same type of misperception effect as say primary factors because size effect is correlated with a statistical preference whereas primary factors are directly related to perception; primary factors such as release and voicing involve acoustic cues which can directly influence the perception of C vs. CV.

3.2.5 Results

3.2.5.1 Overall accuracy

There was a total of 3960 responses (132 nonce forms X 30 participants). For all stimuli, the overall accuracy was very low: the percentage of accurate responses in terms of number of syllables was 46%, as compared to 54% inaccurate responses, so participants performed below chance level. However, the percentage of accurate vs. inaccurate responses varied according to word size: the only forms that received inaccurate responses for the majority of tokens were monosyllables, i.e., monosyllables were perceived incorrectly 66% of the time while disyllables and trisyllables were inaccurately perceived 40% and 27%, respectively. Figure 3.1 summarizes the total number of accurate and inaccurate responses for each word size, and the percentage of accurate vs. inaccurate responses within the total responses for that category.

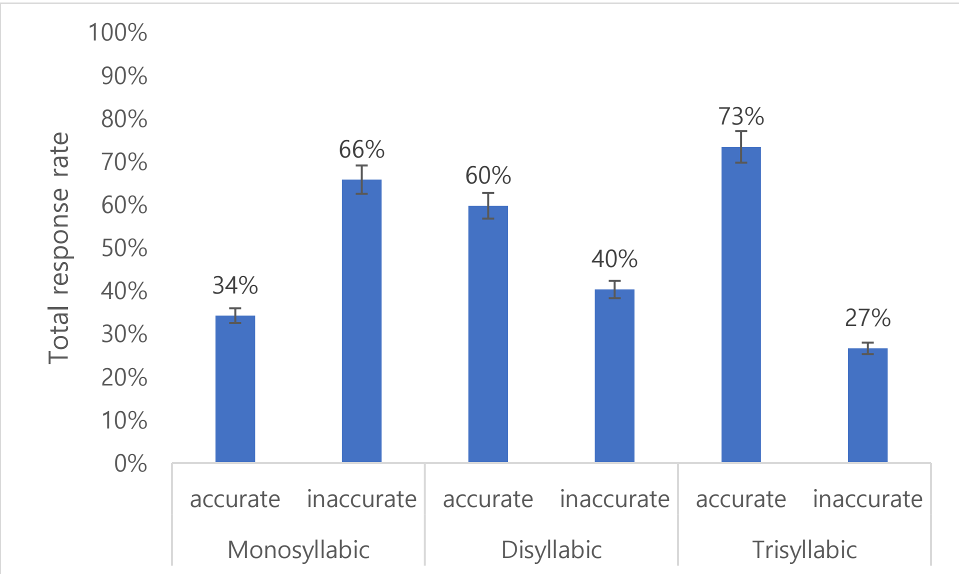

Figure 3.1. Total percent of accurate vs. inaccurate responses for each word size (Error bars indicate 95% confidence intervals)

The types of inaccurate responses in the syllable counting task include both overcounting and undercounting the number of syllables in the stimulus. However, as Table 3.3 shows, almost all of the inaccurate responses for each word size involved overcounting the number of syllables, with only 14 of the 2150 inaccurate responses showing undercounting.

Table 3.3. Syllable counting inaccuracy for each category

Word size	Type of responses	Inaccurate responses by perceived syllable count	Percentage
Monosyllabic (Inaccurate responses = 1664)	Overcounting responses = 100% (1664/1664)	2-syllable	67% (1118/1664)
		3-syllable	33% (546/1664)
Disyllabic (Inaccurate responses = 290)	Undercounting responses = 1% (3/290)	1-syllable	1% (3/290)
	Overcounting responses = 99% (287/290)	3-syllable	91% (264/290)
		4-syllable	8% (23/290)
Trisyllabic (Inaccurate responses = 196)	Undercounting responses = 6% (11/196)	2-syllable	6% (11/196)
	Overcounting responses = 94% (185/196)	4-syllable	89% (175/196)
		5-syllable	5% (10/196)

The majority of overcounting responses involved hearing only one extra syllable: 67% of the inaccurate responses for monosyllables, 91% for disyllables, and 89% for trisyllables fall into this category. Only monosyllables had a substantial number of responses indicating two extra syllables: 33% for monosyllables vs. 8% and 5% for disyllables and trisyllables, respectively.

The responses involving overcounting by more than one syllable, as well as the small number of undercounting responses (1% and 6% for disyllables and trisyllables, respectively) were not predicted by the adaptation-in-perception approach. I will discuss possible explanations of these responses in Section 3.2.6, focusing here on responses that involved overcounting by one extra syllable.

3.2.5.2 Statistical analysis

The results from the syllable counting experiment indicated that Korean participants were more likely to perceive an extra syllable (i) when the English final stop was released than when it was unreleased, and (ii) when it was preceded by a tense vowel than when it was preceded by a lax vowel, as shown in Figure 3.2. All the statistical models built for the task found significant effects of stop release and vowel tenseness and no effect for the other factors (Tables 3.5, 3.7, 3.8, and 3.9).

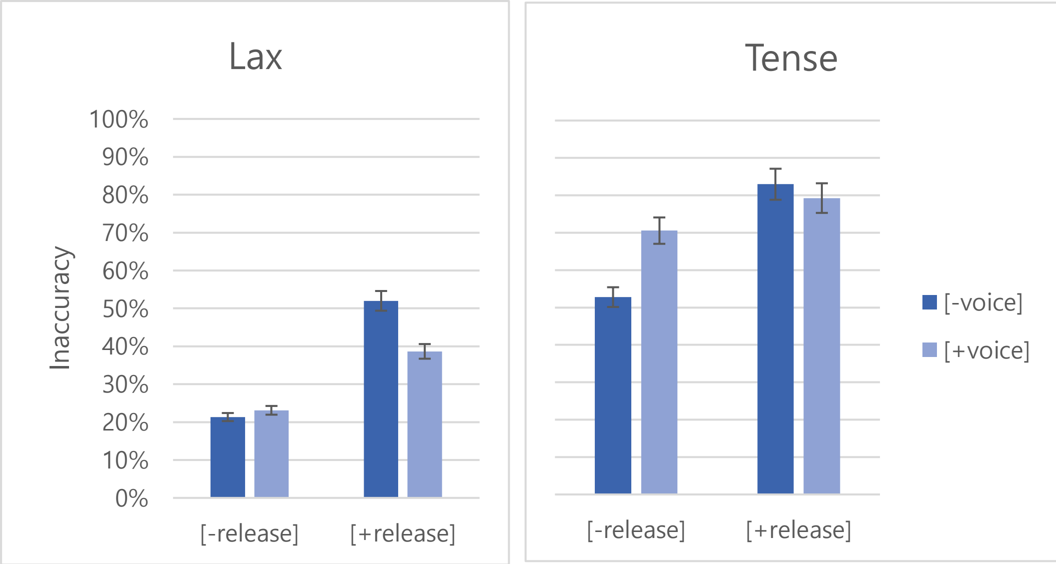

Figure 3.2. Syllable counting inaccuracy by release and voicing in forms with lax pre-stop vowels and in forms with tense pre-stop vowels (Error bars indicate 95% confidence intervals)

The syllable counting inaccuracy was modeled using a series of mixed effects logistic regression models, implemented in the *lme4* package (Bates et al. 2015) in R (R Development Core Team 2016). The counting measure was calculated by first building a model for the three primary factors (stop release, stop voicing, and tenseness of pre-stop vowel). Then, three separate models were built by adding each of the non-primary factors (final stress, stop place, and word size) to the model of the primary factors (see Table 3.4). For all four models, the dependent variable was the participants' response (whether participants' syllable counting is accurate or not). Accurate responses for monosyllabic items were 1-syllable, and answers other than 1-syllable for monosyllabic items (2-syllable and 3-syllable responses) were inaccurate. Accurate responses for disyllabic items were 2-syllable, and answers other than 2-syllable for disyllabic items (3-syllable and 4-syllable responses) were inaccurate. Accurate responses for trisyllabic items were 3-syllable, and answers other than 3-syllable for trisyllabic items (4-syllable and 5-syllable responses) were inaccurate.

Fixed effects included six linguistic factors, stop release (unreleased or released), stop voicing (voiceless or voiced), tenseness of pre-stop vowel (lax or tense), stress of final syllable (unstressed or stressed), stop place (labial, coronal or dorsal), and word size (monosyllabic or polysyllabic). Interactions of the primary factors (release, voicing, vowel tenseness) were also included in all four models. Two-level factors including Release, Voicing, Tenseness, Stress, and Size were deviation-coded (Release: [-release] = -0.5, [+release] = 0.5; Voicing: [-voice] = -0.5, [+voice] = 0.5; Tenseness: lax = -0.5, tense = 0.5; Stress: [-stress] = -0.5, [+stress] = 0.5; Size: monosyllabic = -0.5, polysyllabic = 0.5). Place was coded using forward difference coding (Place1 [labial vs. coronal]: labial = 0.6, coronal = -0.3, dorsal = -0.3; Place2 [coronal vs. dorsal]: labial = 0.3, coronal = 0.3, dorsal = -0.6). Random effects included participants and items; random intercept model converged and only a random intercept was included for both participants and items. Follow up post-hoc comparisons were conducted using Tukey's HSD tests of *multcomp* package (Hothorn et al. 2008). The four regression models are given in Table 3.4 and their outputs are summarized in Tables 3.5, 3.7, 3.8, and 3.9.

Table 3.4. Models for the syllable counting task

Model.basic	glmer (Response ~ RELEASE * VOICING * TENSENESS + (1|subject) + (1|item), data = Syllable, family="binomial")
Model.stress	glmer (Response ~ RELEASE * VOICING * TENSENESS + STRESS + (1|subject) + (1|item), data = Syllable, family="binomial")
Model.place	glmer (Response ~ RELEASE * VOICING * TENSENESS + PLACE + (1|subject) + (1|item), data = Syllable, family="binomial")
Model.size	glmer (Response ~ RELEASE * VOICING * TENSENESS + SIZE + (1|subject) + (1|item), data = Syllable, family="binomial")

The output of the first model is given in Table 3.5. In this model, the main effect of Release was significant ($z = 5.204$, $p < 0.001$); Korean participants were more likely to hear an extra syllable when the English final stop was released than when it was unreleased. This result is consistent with the prediction of the adaptation-in-perception approach, but inconsistent with the adaptation-in-production view since the former predicted a greater likelihood of syllable overcounting in released stops than unreleased stops whereas the latter predicted no significant release effect for the task.

Table 3.5. The output of Model.basic

	Estimate	St. Error	z-value	Pr (>|z|)
(Intercept)	0.224	0.429	0.522	0.601
Release ([-rel] vs. [+rel])	1.996	0.383	5.204	<0.001 ***
Voicing ([-voice] vs. [+voice])	0.118	0.381	0.311	0.756
Tenseness (lax vs. tense)	3.503	0.389	8.987	<0.001 ***
Release * Voicing	-1.468	0.762	-1.927	0.054 .
Release * Tenseness	-0.195	0.762	-0.256	0.798
Voicing * Tenseness	1.254	0.763	1.645	0.100
Release * Voicing * Tenseness	-1.201	1.525	-0.787	0.431

Significant codes: <0.001 '***'; <0.01 '**'; <0.05 '*'; <0.1 '.'

This model also found a significant effect of Tenseness ($z = 8.987$, $p < 0.001$). Figure 3.3 clearly shows the difference between forms with lax vowels vs. forms with tense vowels; participants were more likely to overcount when the final stop was preceded by a tense vowel than when it was preceded by a lax vowel. I will discuss inaccuracy for lax vs. tense monophthong items as well as inaccuracy for tense monophthong vs. diphthong items in Section 3.2.6.

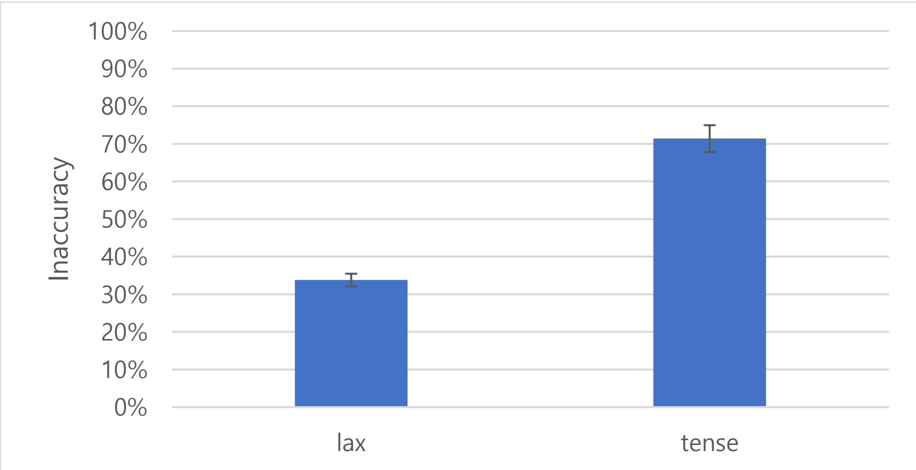

Figure 3.3. Syllable counting inaccuracy according to vowel tenseness (Error bars indicate 95% confidence intervals)

In the first model given in Table 3.5, Voicing did not have a significant main effect ($p = 0.756$), and there was a marginal interaction of Release * Voicing ($p = 0.054$). As shown in Table 3.6, Tukey's HSD test of Release * Voicing indicated that the predicted voicing effect (a greater likelihood of syllable overcounting in voiced stops) was not significant for both unreleased and released conditions: the differences between voiced vs. voiceless conditions were not significant when the final stop was unreleased ($p = 0.501$) as well as when it was released ($p = 0.842$).[21]

Table 3.6. Pairwise comparisons: results from Tukey HSD post-hoc analyses on the model of interaction of release * voicing

Comparisons	**Estimate**	**St. Error**	**z-value**	**Pr (>|z|)**
[-rel]:[+voice] – [+rel]:[+voice]	-1.243	0.705	-1.764	0.290
[+rel]:[-voice] – [+rel]:[+voice]	0.580	0.702	0.825	0.842
[-rel]:[-voice] – [-rel]:[+voice]	-0.986	0.706	-1.396	0.501
[-rel]:[-voice] – [+rel]:[-voice]	-2.810	0.707	-3.975	<0.001 ***

Significant codes: <0.001 '***'; <0.01 '**'; <0.05 '*'; <0.1 '.'

The second model in Table 3.7 found significant main effects of Release ($z = 5.216$, $p < 0.001$) and Tenseness ($z = 8.060$, $p < 0.001$), as in the first model. The main effect of Stress was not significant ($p = 0.534$), suggesting that participants were not more likely to hear an extra syllable when the final syllable was stressed than when it was unstressed. This result is consistent with the prediction of the two approaches that there would be no significant stress effect because factors that might be influenced by stress, such as release of the final stop and length of the pre-stop vowel, were controlled for in this task.

[21] The effect of voicing was not found even when diphthong items were removed: pairwise comparisons with Tukey's HSD test of release * voicing interaction indicated that the voicing effect was not significant when the final stop was unreleased ($p = 0.144$) and when it was released ($p = 0.225$).

Table 3.7. The output of Model.stress

	Estimate	St. Error	z-value	Pr (>|z|)
(Intercept)	0.329	0.461	0.713	0.475
Release ([-rel] vs. [+rel])	1.997	0.383	5.216	<0.001 ***
Voicing ([-voice] vs. [+voice])	0.118	0.380	0.312	0.754
Tenseness (lax vs. tense)	3.645	0.452	8.060	<0.001 ***
Stress ([-stress] vs. [+stress])	-0.352	0.568	-0.621	0.534
Release * Voicing	-1.470	0.761	-1.932	0.053 .
Release * Tenseness	-0.199	0.760	-0.262	0.793
Voicing * Tenseness	1.253	0.761	1.646	0.099 .
Release * Voicing * Tenseness	-1.197	1.522	-0.786	0.432

Significant codes: <0.001 '***'; <0.01 '**'; <0.05 '*'; <0.1 '.'

The output of the next model given in Table 3.8 shows the same results as in the first two models: there were significant main effects of Release ($z = 5.244$, $p < 0.001$) and Tenseness ($z = 9.049$, $p < 0.001$). In this model, Place1 (labial vs. coronal) and Place2 (coronal vs. dorsal) did not have a significant main effect (labial vs. coronal: $p = 0.232$; coronal vs. dorsal: $p = 0.397$), suggesting that participants were not significantly more likely to perceive an extra syllable when the English final stop was coronal than when it was labial or dorsal. Tukey's HSD test of stop place indicated that the differences between labial vs. dorsal stops were also not significant ($p = 0.457$). These results are consistent with the predictions of both approaches that there would be no significant effect of stop place (including morphological alternation effect) in the task because final stop release was strictly controlled in the stimuli of the task and because it is likely that participants of the task were considering simple acoustic similarity between surface forms rather than similarity of the entire paradigm.

Table 3.8. The output of Model.place

	Estimate	St. Error	z-value	Pr (>|z|)
(Intercept)	0.223	0.429	0.521	0.602
Release ([-rel] vs. [+rel])	1.995	0.380	5.244	<0.001 ***
Voicing ([-voice] vs. [+voice])	0.118	0.377	0.313	0.754
Tenseness (lax vs. tense)	3.501	0.386	9.049	<0.001 ***
Place1 (lab vs. cor)	-0.551	0.461	-1.193	0.232
Place2 (cor vs. dor)	0.390	0.460	0.847	0.397
Release * Voicing	-1.469	0.756	-1.943	0.052 .
Release * Tenseness	-0.198	0.756	-0.263	0.792
Voicing * Tenseness	1.249	0.756	1.652	0.098 .
Release * Voicing * Tenseness	-1.195	1.513	-0.790	0.429

Significant codes: <0.001 '***'; <0.01 '**'; <0.05 '*'; <0.1 '.'

Table 3.9 gives the output of the last model where there were significant main effects of Release (z = 5.214, p < 0.001) and Tenseness (z = 5.532, p < 0.001), just like in all the other models. The main effect of Size was not significant (p = 0.560), indicating that participants were not significantly more likely to overcount when the English nonce word was monosyllabic than when it was polysyllabic.

Table 3.9. The output of Model.size

	Estimate	**St. Error**	**z-value**	**Pr (>|z|)**
(Intercept)	0.263	0.435	0.606	0.544
Release ([-rel] vs. [+rel])	2.001	0.383	5.214	<0.001 ***
Voicing ([-voice] vs. [+voice])	0.116	0.380	0.307	0.758
Tenseness (lax vs. tense)	3.837	0.693	5.532	<0.001 ***
Size (monosyllabic vs. polysyllabic)	-0.413	0.709	-0.583	0.560
Release * Voicing	-1.465	0.762	-1.923	0.054 .
Release * Tenseness	-0.203	0.762	-0.267	0.789
Voicing * Tenseness	1.257	0.762	1.649	0.099 .
Release * Voicing * Tenseness	-1.206	1.523	-0.792	0.428

Significant codes: <0.001 ‘***’; <0.01 ‘**’; <0.05 ‘*’; <0.1 ‘.’

In this section, the statistical analysis of the results showed that there were significant main effects of stop release and tenseness of pre-stop vowel. All four models had these same effects and three different extra factors did not change the significance results found in the very first model (Model.basic, Table 3.5). None of the extra predictors turned out to have a significant main effect, and there were no significant interactions between the factors.

3.2.6 Discussion

In the syllable counting task, I found that two linguistic factors led to a greater likelihood of syllable overcounting: an extra syllable was more likely to be heard in forms ending in released stops and in forms in which the final stop was preceded by a tense vowel. I will discuss the relationship between these findings and the two approaches in this section, first dealing with the low accuracy of unreleased stops, and then turning to the effect of vowel tenseness.

Low accuracy of unreleased stops

As mentioned in Section 3.2.5.1, the overall accuracy in syllable counting was very low (46%). It is interesting that participants performed overall below chance level. A more surprising result is that items ending in unreleased stops showed relatively higher inaccuracy than expected: participants perceived an additional syllable in 44% of the forms that ended in an unreleased stop, as shown in Figure 3.4. This is an intriguing finding because release is proposed by Kang (2003) to be the major factor accounting for Korean speakers' vowel epenthesis following English final stops. This result suggests that release alone is not sufficient to account for perception of an illusory vowel.

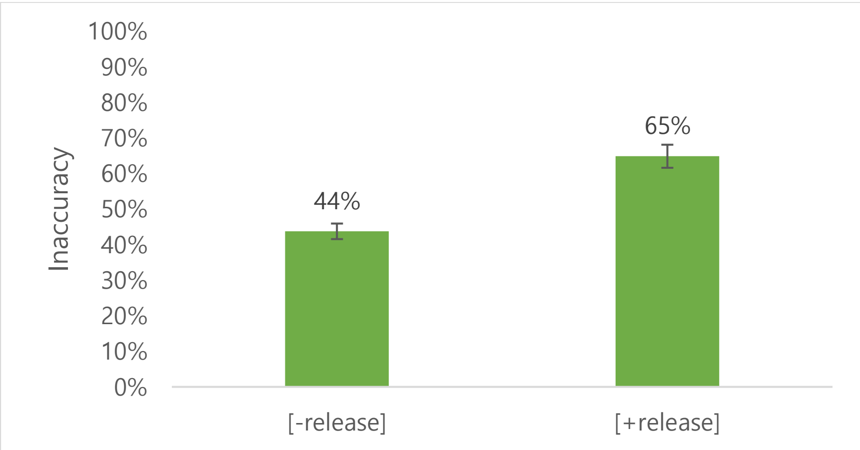

Figure 3.4. Syllable counting inaccuracy according to release of the final stop (Error bars indicate 95% confidence intervals)

The lower accuracy for forms ending in unreleased stops might be correlated with the effect of vowel tenseness. As shown in Section 3.2.5.1, monosyllabic words had two different types of inaccurate responses, i.e., disyllabic and trisyllabic responses. The responses indicating two extra syllables were not predicted by the adaptation-in-perception hypothesis, which focused only on the possibility of perceiving final C as CV, so it is of some interest that a difference was found. Table 3.10 shows that there was a relationship between vowel tenseness and trisyllabic responses. No monosyllabic forms containing lax vowels received 3-syllable responses, while 32% of monosyllabic forms with tense vowels received 3-syllable responses. In contrast, almost all the words with lax vowels received disyllabic responses.

Table 3.10. Syllable overcounting for monosyllabic words

Word size	Inaccurate responses	Vowels preceding final stop	Syllable overcounting (number of inaccurate responses out of total inaccurate responses for monosyllabic words)
Monosyllabic	2-syllable	Lax	7% (114/1664)
		Tense	60% (1004/1664)
	3-syllable	Lax	<1% (8/1664)
		Tense	32% (538/1664)

The tendency to overcount forms containing tense vowels may be explained by the sound system of the Korean language.[22] Unlike English, Korean does not allow diphthongs within a single syllable (Sohn 1999). That is, a one-syllable English word like *game* becomes a two-syllable word pronounced by Koreans as something like /ge.im/. For example, two monosyllabic stimuli of the syllable counting task may have different syllabifications: a monosyllabic form with a lax vowel such as [kʰɛp] can be syllabified as /.kʰɛp˺./ or /.kʰɛ.pʰɨ./, while a monosyllabic form with a tense vowel such as [zaɪp] can be syllabified as /.za.ip˺./ or /.za.i.pʰɨ./. Thus, my Korean speakers could have analyzed [kʰɛp] either as /.kʰɛp˺./ or as /.kʰɛ.pʰɨ./; and [zaɪp] as /.zajp˺./ or as /.za.ip˺./ or /.za.i.pʰɨ./; and because /.zaɪp˺./ does not correspond to the syllable structure of the Korean language, which only admits one vowel in one syllable, the Korean speakers who correctly identified the word as monosyllabic may have had greater familiarity with English.

In order to exclude this possibly confounding vowel tenseness effect, Table 3.11 gives the statistics for forms with lax vowels only. As shown in Figure 3.5 (right panel), Korean participants were significantly more likely to overcount when the final stop of the lax items was released than when it was unreleased ($p < 0.001$).

[22] A tendency to count diphthongs as extra syllables could not be examined for disyllabic and trisyllabic items since polysyllabic items did not include tense pre-final vowels. Only lax pre-stop vowels were included for disyllabic and trisyllabic items, as mentioned in Section 2.3.2.

Table 3.11. Accurate vs. inaccurate responses: release in forms with lax vowels

Release	Accurate responses	Inaccurate responses	Accurate	Inaccurate
[-release]	700	200	78%	22%
[+release]	492	408	55%	45%

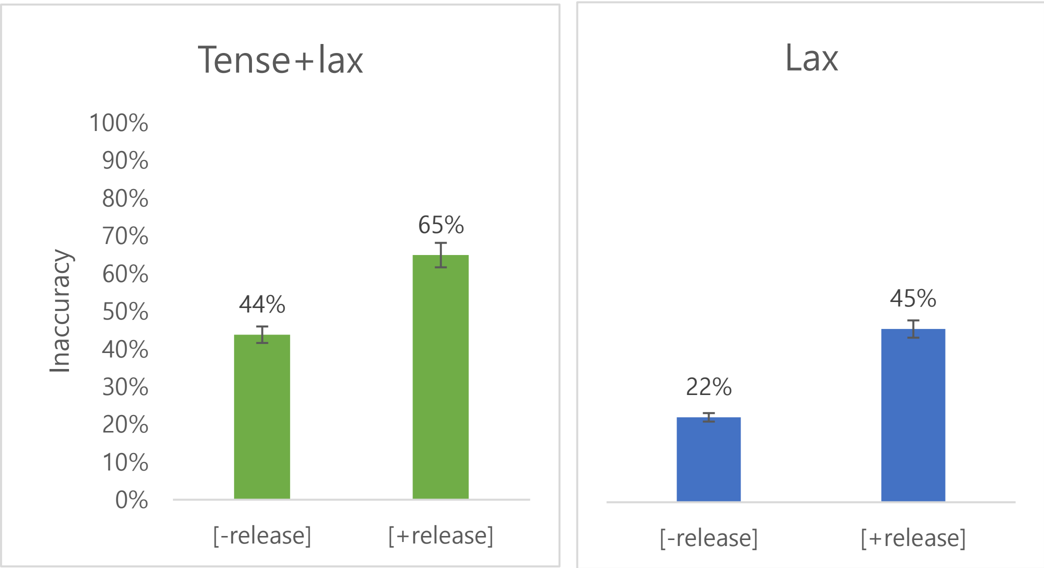

Figure 3.5. Syllable counting inaccuracy according to release of the final stop in total stimuli vs. forms with lax vowels (Error bars indicate 95% confidence intervals)

Comparing the two figures given in Figure 3.5, we see that when all the tense forms are removed from the overcounting responses, the accuracy rate for unreleased stops is much improved. The overall accuracy also improves when only lax forms are considered, as shown in Figure 3.6, so it is clear that release is not the only factor with a noticeable effect on overcounting and other factors like vowel tenseness are also clearly playing an important role even in the absence of release.

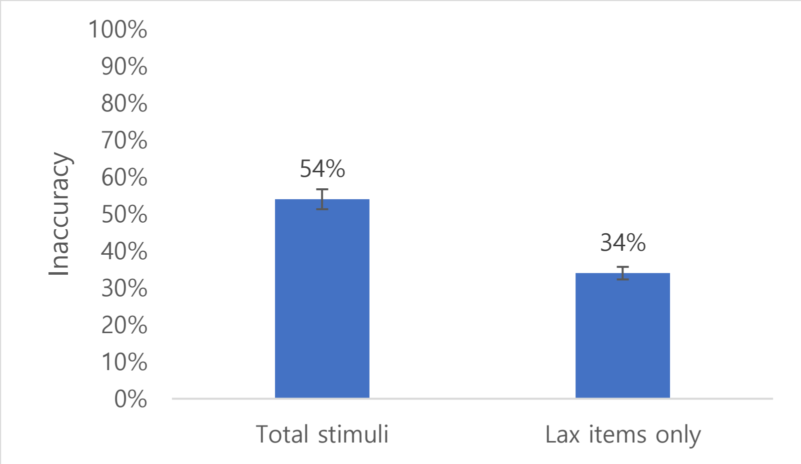

Figure 3.6. Syllable counting inaccuracy of total stimuli vs. forms with lax vowels (Error bars indicate 95% confidence intervals)

However, one thing to note here is that the inaccuracy was 22% even for items ending in unreleased stops with lax vowels, as shown in Figure 3.5 (right panel). Taking voicing into account, Figure 3.7 shows that the inaccuracy was still over 20% for items ending in unreleased voiceless stops (those closest to legal Korean final stops) preceded by lax vowels (21%). This result is difficult to explain in terms of release or voicing of the final stop or tenseness of pre-final vowel. It is possible that the syllable counting task was not straightforward for Korean speakers. Even though they indicated that they were familiar with the definition of a syllable, it is possible that they did not completely understand this concept when they were faced with English nonce forms. It is plausible that they repeated the items to themselves in a way in which they usually pronounce existing loanwords (e.g., *peak* -> [p^hik^hɨ]), and then they counted the number of syllables for those forms. This would account for the low overall accuracy in this task (46%), and the relatively high inaccuracy (21%) for items ending in unreleased voiceless stops with lax vowels might just arise from task effects.

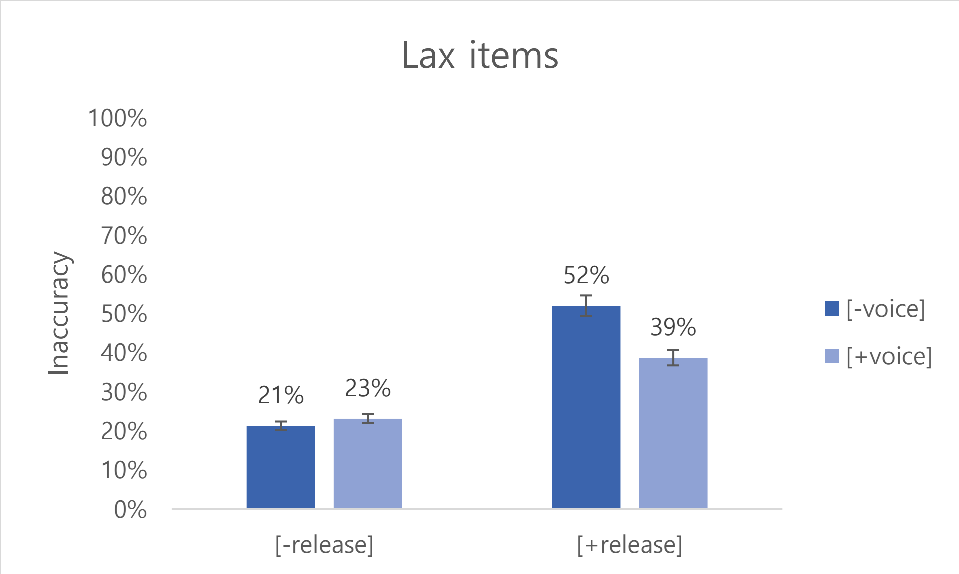

Figure 3.7. Syllable counting inaccuracy according to release and voicing in forms with lax vowels (Error bars indicate 95% confidence intervals)

Vowel tenseness effect

In Section 3.2.5.2, I discussed the relationship between forms with lax vs. tense pre-final vowels. The results showed that forms with tense vowels were statistically more likely to be inaccurately counted than forms with lax vowels ($p < 0.001$, Figure 3.3). However, as mentioned before, Korean speakers tend to overcount forms containing tense vowels because of Korean phonotactics, i.e., a diphthong is not allowed within a single syllable and only one vowel must be the peak of a syllable in Korean. In order to examine the effect of diphthongs vs. tenseness, tense vowels were distinguished by type: long nuclei that do not have a change in vowel quality such as [i:] and [u:] vs. obvious diphthongs that do change vowel quality such as [aɪ], [eɪ], [oɪ], and [oʊ]. Table 3.12 compares syllable counting responses for the two categories (diphthongs vs. monophthongs).

Table 3.12. Accurate vs. inaccurate responses: tense vowels in monosyllables

Tense vowels	Accurate responses	Inaccurate responses	Accuracy	Inaccuracy
Diphthong (e.g., [ei])	221	1219	15%	85%
Monophthong (e.g., [i:])	397	323	55%	45%

Note that Table 3.12 considers responses only for monosyllabic words because polysyllabic words contained no tense vowels, as mentioned in Section 2.3.2. Overcounting was much more likely when the tense vowel was an obvious diphthong like [eɪ] than when it was a monophthong like [i:]. That is, the forms whose nuclei contain two different qualities were more likely to be interpreted by Korean participants as heterosyllabic than those analyzed as a tense monophthong like [i:].

To remove the effect of diphthongs, Figure 3.8 shows syllable counting inaccuracy according to release, voicing and vowel tenseness for forms containing lax vowels vs. tense monophthongs. A post-hoc test with Tukey's HSD indicated that illusory vowel perception was more likely when the final stop was released than when it was unreleased ($p < 0.001$), whereas the difference between lax vs. tense monophthong items was not significant ($p = 0.149$). As shown in Figure 3.8, unreleased voiceless items even had lower inaccuracy for tense monophthong items than for lax items. This result is possibly attributed to the vowel duration of the stimuli. As discussed in Section 2.3.2.1, the mean duration of lax pre-stop vowels in the stimuli was actually longer than that of tense monophthongs (145ms vs. 101ms). It is possible that the syllable counting inaccuracy was not statistically different for lax vs. tense monophthong items since participants heard the auditory items where lax vowels were longer than tense monophthongs. We might get a different result from a task where tense monophthongs have longer mean duration than lax vowels in the stimuli.

Figure 3.8. Syllable counting inaccuracy by release and voicing in forms with lax pre-stop vowels and in forms with tense monophthongs (Error bars indicate 95% confidence intervals)

A study by Kwon (2017) provides evidence that the tense vowel effect cannot be fully accounted for only by the greater likelihood of release in English pronunciation after tense vowels, as proposed by Kang (2003). Kwon probed Korean speakers' perception of nonce forms by asking Korean speakers to choose the appropriate allomorph of suffixes that have two allomorphs, one used after stems ending in a vowel and the other after stems ending in a consonant. In an experiment where Korean participants listened to English non-words ending in a plosive and selected an appropriate suffix after each stimulus,[23] Kwon (2017) controlled the presence/absence of stop release by excising the release portion of released items. The effect of tense vowels preceding the stem-final consonant was still found in unreleased items (about 40% of vowel insertion in unreleased tense items for near monolingual speakers, see Kwon 2017: 11). Similarly, my experimental results showed 26% inaccuracy in forms ending

[23] Korean case markers have two allomorphs, consonant-initial and vowel-initial. Their distribution is phonologically conditioned by the presence of a coda in the preceding noun. For example, when the preceding noun ends in a vowel, the consonant-initial allomorph occurs (e.g., imo 'aunt' → imo-lɨl 'aunt-ACC'); when the noun ends in a consonant, the vowel-initial allomorph occurs (e.g., samtʃʰon 'uncle' → samtʃʰon-ɨl 'uncle-ACC')

in unreleased stops with tense monophthongs, even though stop release was controlled for in the stimuli. However, in my task the vowel tenseness effect might have been confounded with the word size effect, since tense vowels were included only for monosyllabic items. That is, the low accuracy for the items with tense monophthongs might be due to the fact that monosyllables are not preferred in Korean.[24]

Undercounting responses

We saw in Section 3.2.5.1 that a small percentage of the polysyllabic words were undercounted: 3 monosyllabic responses for disyllabic words and 11 disyllabic responses for trisyllabic words (0.7% of total inaccurate responses). 3 different disyllabic words received 3 undercounting responses from 3 different participants and those words shared no common factors. 7 different trisyllabic words received 11 undercounting responses from 4 different participants and there also were no factors in common. One participant gave undercounting responses for both disyllabic and trisyllabic words. These 14 undercounting responses out of 2150 inaccurate responses are probably accidental mistakes, made by only 5 participants.

We have looked at syllable counting inaccuracy in terms of each linguistic factor and different predictions of the two approaches. First, the adaptation-in-perception approach predicted that Korean participants would perceive an extra syllable since they inaccurately hear an English final stop as being CV when the final stop is released or voiced, when it is preceded by a tense vowel, and when it occurs in a monosyllable. This approach predicted no significant effects in stop place and final stress because final stop release was controlled across each category of place and stress in the stimuli. This view also predicted no significant effect in morphological alternation since the final consonant of Korean nouns can surface as a coronal stop which means that Koreans would take English words ending in a coronal stop to be legal in Korean. On the other hand, the adaptation-in-production approach predicted that acoustic factors would not affect Korean participants' perception of the number of syllables in the

[24] All the experimental items used in Kwon's (2017) study are also monosyllabic, so a similar issue could arise related to the tense vowel effect, but word size is not a factor she investigates; she considers only four factors in her study, i.e., release, voicing, place, and vowel tenseness.

English forms since they accurately hear an English final stop as consonant-final. Thus, this approach predicted no significant effect of the given factors.

We found in the syllable counting task that stop release and vowel tenseness had significant effects: perception of an extra syllable was more likely after (i) released stops than unreleased stops and (ii) stops following a tense vowel than following a lax vowel. This finding is consistent with the adaptation-in-perception approach. No effect was found with respect to the other factors in the syllable counting task: no effect of stop voicing and word size is consistent with the adaptation-in-production approach, and no effect of final stress, stop place, and morphological alternation is consistent with both the adaptation-in-perception and the adaptation-in-production approaches. Thus, the predictions of the syllable counting experiment appear to support the adaptation-in-perception approach, although it is possible that the adaptation-in-production approach was also playing a role. We turn to two other behavioral experiments, a categorization task and a similarity judgment task, for additional empirical evidence for the unnecessary vowel insertion.

Chapter 4
Categorization

As discussed in Chapter 3, results from the syllable counting experiment showed that Korean speakers were more likely to identify an English final stop as a stop followed by a vowel when the final stop was released and when it was preceded by a tense vowel, but the results were not sufficient to determine which approach provides a better fit with the unnecessary vowel epenthesis. Thus, in this chapter I report on an additional perception experiment to examine how foreign forms are perceived. In the categorization task Korean participants categorized English stop-final and vowel-final forms in a forced choice task where they were asked whether the form ended in a consonant. This experiment was designed to test the effects of the same linguistic factors that were considered in the syllable counting experiment and to investigate participants' ability to accurately perceive English stop-final forms.

4.1 Categorization experiment

4.1.1 Participants

A different participant group was recruited for the categorization task than for the syllable counting task. The participants in this task were 30 Korean native speakers who were undergraduate and graduate students at Sogang University in Seoul, South Korea. 11 participants were male and 19 were female. Participants ranged in age from 21 to 38, with an average age of 27.6 at the time of participation (SD=5.4). The average age of first exposure to English study was 10.1 years old (SD=2.0). No participants were English majors or had lived in an English-speaking country at the time of the experiment. No participants reported any speech or hearing disorders. All participants volunteered to participate in the experiment and were given a monetary compensation upon completing the task.

4.1.2 Stimuli and procedure

The 30 Korean participants each listened to 198 pseudo-English target items including nonce words ending in a consonant as well as nonce words ending in a vowel. The number of consonant-final English non-words was 132 and the number of vowel-final English non-words was 66. The 132 consonant-final English nonce words were the same items as the ones used in the production task and the syllable counting task. In the categorization experiment, consonant-final nonce words ended in stops and vowel-final nonce words always ended in a barred i [ɨ]. All the nonce words were recorded by a balanced Korean-English bilingual speaker who was able to properly produce the vowel [ɨ] while otherwise keeping English pronunciation. The entire set of auditory stimuli including filler items is presented in Appendix 3.

Participants were directed to listen to the auditory stimuli and to answer the following question for each stimulus: Do you think that the word ends in a consonant? A coda consonant is called *pachim* in Korean; thus, before the start of the task, the experimenter explained to participants that the question of "Does the word end in a consonant?" would mean the same as that of "Does the final syllable of the word have a *pachim*?" and that they should choose answer Yes if they thought that the word had a *pachim* or answer No if they thought that the word did not have a *pachim*. Participants were told that they would be hearing English nonce forms that would sound just like English words but would not be found in an English dictionary. Directions were given in Korean by the experimenter (the author), and the test question was given in English on a computer monitor as indicated in Figure 4.1. Most of the participants understood the concept of the question without difficulty.[25]

Participants were given no orthographic or other information but only auditory information through a laptop computer. They listened to stimuli using a headphone in a sound-attenuated room in the English Department at Sogang University. Participants had a short practice round before the actual task. Praat's ExperimentMFC was used in this experiment where the stimuli were sounds and the responses were categories (Yes or No) whose labels

[25] Out of 30 participants, only one subject expressed difficulty making a choice. This subject wanted to stop a minute after the categorization task had started because he did not fully understand what to do. The methodology was explained to the subject again and he finished the task, but his results showed that he did not understand the experiment very well even at the second trial. I will discuss this in more detail in Section 4.1.4.3.

appeared on buttons, as shown in Figure 4.1. Participants were asked to click on one of choices which were shown as labelled rectangles.

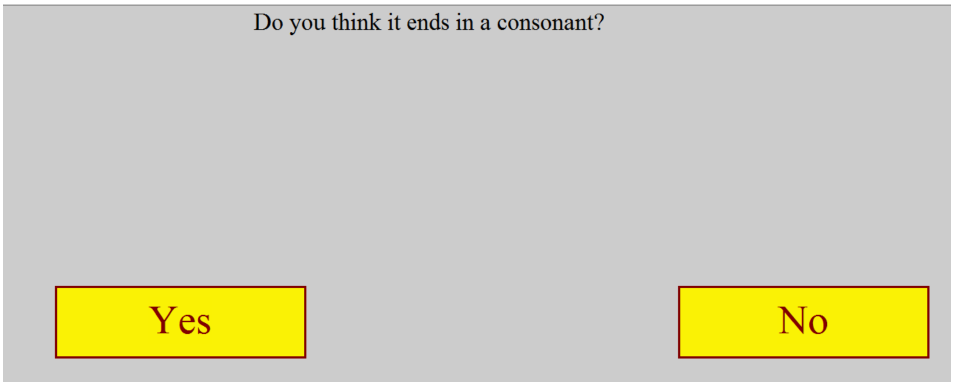

Figure 4.1. Response screen for the categorization experiment

Participants needed to click on their choice in order to hear the next stimulus. That is, a new stimulus arrived when participants made their choice. They heard the stimulus only once; they could not go back to hear an item again even if they wanted to. Listeners heard 219 different stimuli including filler items, and the order of the stimuli was randomized for each subject. Each participant had a short break after every 51 trials. This task took about ten minutes to complete, and participants were paid for their participation.

4.1.3 Predictions

Table 4.1 shows the predictions of the adaptation-in-production approach. This hypothesis would predict that since Korean listeners accurately perceive an English final stop as a final consonant, they will categorize English CVC as CVC even if the primary factors create a structure that is acoustically similar to the Korean vowel. Thus, according to this hypothesis, there should be no significant effects of all the given factors, as shown in Table 4.1.

Table 4.1. Predictions of the adaptation-in-production approach for categorization task

Linguistic factors		Predictions
Primary factors	**Stop release**	There will be no significant difference in the categorization between an English word ending in a released stop and an English word ending in an unreleased stop.
	Stop voicing	There will be no significant difference in the categorization between an English word ending in a voiced stop and an English word ending in a voiceless stop.
	Vowel tenseness	There will be no significant difference in the categorization between an English word with tense pre-final vowel and an English word with lax pre-final vowel.
Secondary factors	**Stop place (labials vs. dorsals)**	There will be no significant difference in the categorization between an English word ending in a labial stop and an English word ending in a dorsal stop.
	Final stress	There will be no significant difference in the categorization between an English word ending in a stressed syllable and an English word ending in an unstressed syllable.
Other factors	**Morphological alternation (coronals)**	There will be no significant difference in the categorization between an English word ending in a coronal stop and an English word ending in a labial or dorsal stop.
	Word size (phonological markedness)	There will be no significant difference in the categorization between an English monosyllabic word and an English polysyllabic word.

Table 4.2 shows the predictions of the adaptation-in-perception approach. This hypothesis would predict that Korean listeners will categorize English CVC as CVCV because they misperceive the English final stop with specific phonetic characteristics as being CV. It is expected that several factors will have an effect and there are different reasons for each linguistic property: first, release will cause the perception of an illusory vowel since it creates a structure that is phonetically similar to the inserted vowel; second, voicing will also cause Korean listeners to hear an illusory vowel because voicing can occur only between sonorants in Korean; third, vowel tenseness will cause the perception of an illusory vowel because a vowel is longer in an open than in a closed syllable in Korean and tense vowels are longer than lax vowels; and last, there will be a word size effect since monosyllabic words are not preferred in Korean and the dispreference for monosyllables can bias listeners toward hearing an extra syllable in monosyllabic forms.

However, the adaptation-in-perception hypothesis will not predict significant effects in stop place, final stress, and morphological alternation for the following reasons: first, release was strictly balanced across each category of place and stress in the categorization task; and second, Korean nouns can end in coronal stops on the surface so that there is no reason to make Korean listeners think that English words cannot end in coronal stops.

Table 4.2. Predictions of the adaptation-in-perception approach for categorization task

Linguistic factors		**Predictions**
Primary factors	**Stop release**	An English word ending in a released stop will be more likely to be categorized as vowel-final than an English word ending in an unreleased stop.
	Stop voicing	An English word ending in a voiced stop will be more likely to be categorized as vowel-final than an English word ending in a voiceless stop.
	Vowel tenseness	An English word ending in a stop will be more likely to be categorized as vowel-final when the English vowel preceding the final stop is tense than when it is lax.
Secondary factors	**Stop place (labials vs. dorsals)**	There will be no significant difference in the categorization between an English word ending in a labial stop and a word ending in a dorsal stop.
	Final stress	There will be no significant difference in the categorization between an English word with a stressed final syllable and a word with an unstressed final syllable.
Other factors	**Morphological alternation (coronals)**	There will be no significant difference in the categorization between an English word ending in a coronal stop and a word ending in a labial or dorsal stop.
	Word size (phonological markedness)	An English word ending in a stop will be more likely to be categorized as vowel-final when the English word is monosyllabic than when it is polysyllabic.

4.1.4 Results

4.1.4.1 Overall results

There was a total of 5940 responses (198 stimuli X 30 participants). For all stimuli, 44% of consonant-final English nonce words were identified as consonant-final, as opposed to 6% of vowel-final English nonce words, as shown in Table 4.3. Here, 44% was calculated on the number of ‘word ends in consonant’ responses for consonant-final words out of the total number of responses for consonant-final words, and 6% was calculated on the number of ‘word ends in vowel’ responses for vowel-final words out of the total number of responses for vowel-final words.

Table 4.3. Consonant-final vs. vowel-final responses

Final	C-final responses	V-final responses	C-final responses	V-final responses
C-final words	1758	2202	44%	56%
V-final words	113	1867	6%	94%

Korean speakers were significantly more likely to categorize consonant-final English nonce words as consonant-final than vowel-final English nonce words ($p < 0.001$); yet they were still more likely to categorize them as vowel-final than as consonant-final (56% vs. 44%), as shown in Table 4.3. This result is particularly connected to my predictions given in Table 4.2 and is discussed in the following section.

4.1.4.2 Consonant-final words

The results from the categorization experiment indicated that Korean participants were more likely to categorize an English final stop as a stop plus vowel (i) when the final stop was released than when it was unreleased, (ii) when it was voiced than when it was voiceless, (iii) when it was preceded by a tense vowel than when it was preceded by a lax vowel, and (iv) when it was dorsal than when it was labial. The effects of release, voicing, and vowel tenseness are visually summarized in Figure 4.2. These three effects were found in all the statistical models built for the task (see Tables 4.5, 4.7, 4.8, 4.9), and Tukey's HSD test of stop place confirmed that there was a place effect. Also, the interaction of release and voicing was significant in all four models, indicating that vowel insertion was more likely when the English final stop was unreleased voiced than when it was unreleased voiceless, and when it was released voiceless than when it was released voiced (see Figure 4.3). Another significant interaction was found between voicing and vowel tenseness: vowel insertion was more likely when an English final voiceless stop was preceded by a tense vowel than when it was preceded by a lax vowel (see Table 4.11).

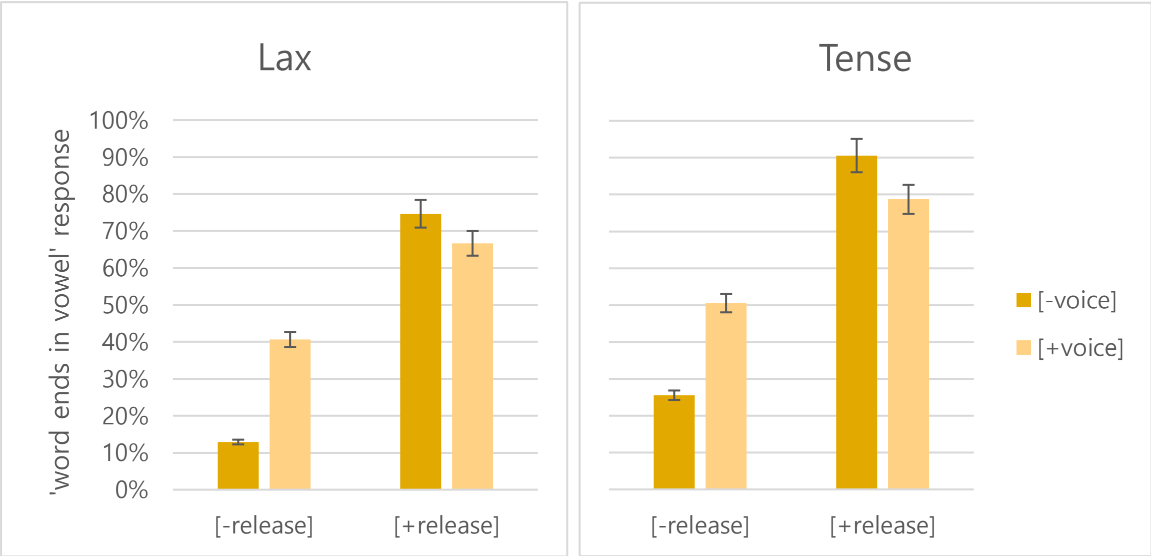

Figure 4.2. Categorization choices by release and voicing in forms with lax vs. tense pre-stop vowels (Error bars indicate 95% confidence intervals)

The presence/absence of an epenthetic vowel reflected in the choice of responses was modeled using several mixed effects logistic regression models, implemented in the *lme4* package (Bates et al. 2015) in R (R Development Core Team 2016). The first model was built for the three primary factors (stop release, stop voicing, and tenseness of pre-stop vowel); then, three additional models were built by adding each of the non-primary factors (final stress, stop place, and word size) to the model of the primary factors (see Table 4.4). For all four models, the dependent variable was the participants' answers (whether participants' response is consonant-final or vowel-final) and it was coded as 0 for responses of 'English word ends in consonant' and 1 for responses of 'English word ends in vowel'.

Fixed effects included six linguistic factors, stop release (unreleased or released), stop voicing (voiceless or voiced), tenseness of pre-stop vowel (lax or tense), stress of final syllable (unstressed or stressed), stop place (labial, coronal or dorsal), and word size (monosyllabic or polysyllabic). Interactions of the primary factors (release, voicing, vowel tenseness) were also included in all of the models. Two-level factors including Release, Voicing, Tenseness, Stress, and Size were deviation-coded, and Place was coded using forward difference coding. Random effects included participants and items; random intercept model converged and only a random intercept was included for both participants and items. Follow up post-hoc comparisons were conducted using Tukey's HSD tests of *multcomp* package (Hothorn et al. 2008). The four regression models are given in Table 4.4 and their outputs are summarized in Tables 4.5, 4.7, 4.8, and 4.9.

Table 4.4. Models for the categorization task

Model.basic	glmer (Response ~ RELEASE * VOICING * TENSENESS + (1|subject) + (1|item), data = Categorization, family="binomial")
Model.stress	glmer (Response ~ RELEASE * VOICING * TENSENESS + STRESS + (1|subject) + (1|item), data = Categorization, family="binomial")
Model.place	glmer (Response ~ RELEASE * VOICING * TENSENESS + PLACE + (1|subject) + (1|item), data = Categorization, family="binomial")
Model.size	glmer (Response ~ RELEASE * VOICING * TENSENESS + SIZE + (1|subject) + (1|item), data = Categorization, family="binomial")

The output of the first model is given in Table 4.5, where a main effect of Release was significant (z = 17.305, p < 0.001); Korean participants were more likely to categorize an English final stop as a stop followed by a vowel when the stop was released than when it was unreleased. This result was consistent with the prediction of the adaptation-in-perception approach, but inconsistent with the adaptation-in-production approach which predicted no significant release effect in the task. The main effect of Voicing was significant (z = 3.071, p < 0.01), indicating that voiced final stops were more likely to be categorized as CV than voiceless final stops, which was again consistent with the prediction of the adaptation-in-perception approach.

Table 4.5. The output of Model.basic

	Estimate	St. Error	z-value	Pr (>|z|)
(Intercept)	0.356	0.226	1.577	0.114
Release ([-rel] vs. [+rel])	2.696	0.155	17.305	<0.001 ***
Voicing ([-voice] vs. [+voice])	0.466	0.151	3.071	<0.01 **
Tenseness (lax vs. tense)	0.924	0.151	6.086	<0.001 ***
Release * Voicing	-2.426	0.304	-7.969	<0.001 ***
Release * Tenseness	0.279	0.303	0.923	0.355
Voicing * Tenseness	-0.576	0.303	-1.902	0.057
Release * Voicing * Tenseness	0.025	0.606	0.042	0.966

Significant codes: <0.001 '***'; <0.01 '**'; <0.05 '*'; <0.1 '.'

In this model given in Table 4.5, there was a significant interaction of Release * Voicing ($z = -7.969$, $p < 0.001$); Figure 4.3 shows the rate of vowel-final responses based on release and voicing of the final stop. As shown in the figure, when final stops were separated into unreleased vs. released, there is a voicing effect in both release conditions: a predicted direction of voicing effect in unreleased stops and a reverse direction of voicing effect in released stops. As shown in Table 4.6, Tukey's HSD post-hoc comparisons of Release * Voicing interaction indicated that the voicing effect was significant in both released and unreleased stops: voiced stops induced more vowel-final responses than voiceless stops did when release was not present ($z = 6.763$, $p < 0.001$) whereas voiceless stops had higher rate of vowel-final responses in released stops ($z = -2.963$. $p < 0.05$). Since both release and voicing were predicted by the adaptation-in-perception approach to lead to more frequent vowel-final responses, I expected the highest rate of vowel-final responses to occur in forms ending in a released voiced stop, and the lowest rate of vowel-final responses in an unreleased voiceless stop. However, as shown in Figure 4.3, while forms ending in unreleased voiceless stops did have the lowest rate, forms ending in released voiceless stops actually had a higher rate of vowel-final responses than forms ending in released voiced stops.

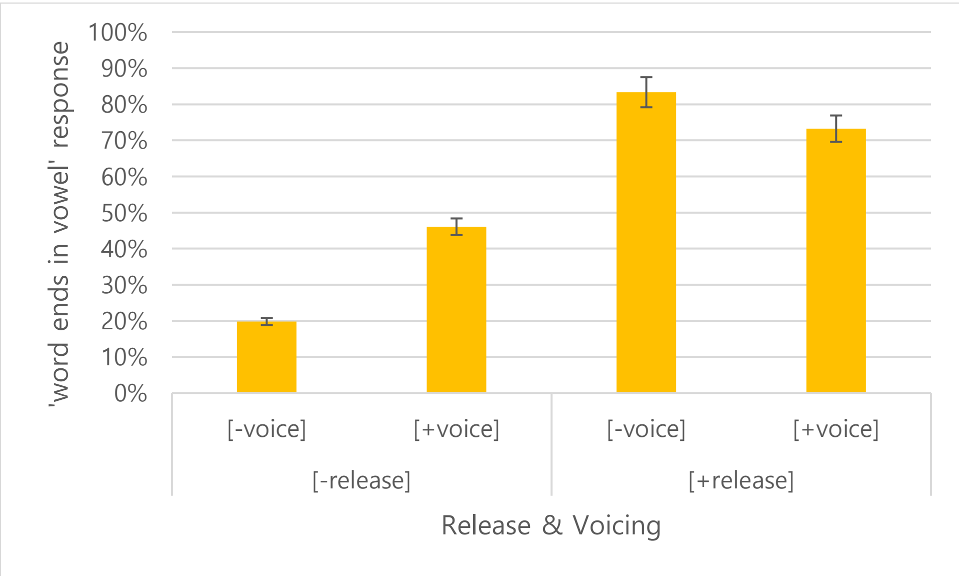

Figure 4.3. Categorization choices by release and voicing of the final stop (Error bars indicate 95% confidence intervals)

Table 4.6. Pairwise comparisons: results from Tukey HSD post-hoc analyses on the model of interaction of release * voicing

Comparisons	Estimate	St. Error	z-value	Pr (>|z|)
[+rel]:[-voice] – [-rel]:[-voice]	3.866	0.254	15.224	<0.001 ***
[-rel]:[+voice] – [-rel]:[-voice]	1.634	0.241	6.763	<0.001 ***
[+rel]:[+voice] – [+rel]:[-voice]	-0.722	0.243	-2.963	<0.05 *
[+rel]:[+voice] – [-rel]:[+voice]	1.509	0.236	6.381	<0.001 ***

Significant codes: <0.001 '***'; <0.01 '**'; <0.05 '*'; <0.1 '.'

The first model given in Table 4.5 also found a significant main effect of Tenseness ($z = 6.086$, $p < 0.001$), which indicates that participants were more likely to categorize an English final stop as a stop followed by a vowel when the stop was preceded by a tense vowel than when it was preceded by a lax vowel (see Figure 4.4). I will discuss the difference between items with lax pre-final vowels and items with tense monophthongs in Section 4.1.5.

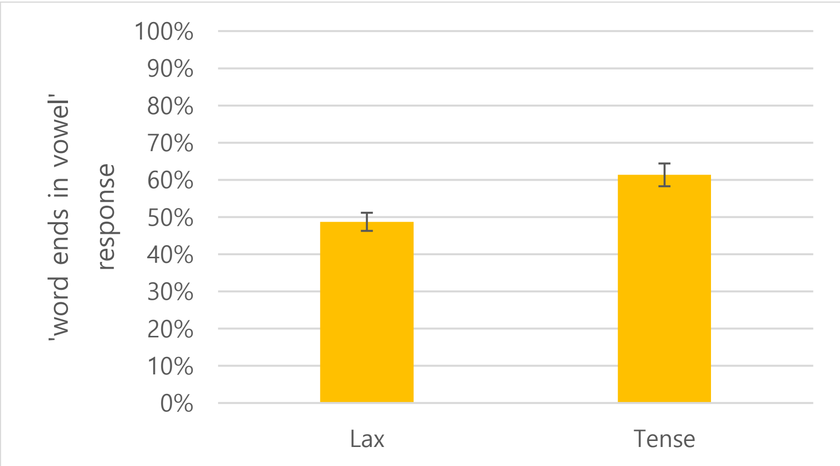

Figure 4.4. Categorization choices by tenseness of pre-stop vowel (Error bars indicate 95% confidence intervals)

The second model in Table 4.7 found significant main effects of Release ($z = 17.327$, $p < 0.001$), Voicing ($z = 3.077$, $p < 0.01$), and Tenseness ($z = 4.928$, $p < 0.001$), and a significant interaction of Release * Voicing ($z = -7.978$, $p < 0.001$), as in the first model. Stress did not have a significant main effect in this model ($p = 0.532$), indicating that stressed items were not significantly more likely to be categorized as CV than unstressed items.

Table 4.7. The output of Model.stress

	Estimate	St. Error	z-value	Pr (>|z|)
(Intercept)	0.314	0.236	1.335	0.182
Release ([-rel] vs. [+rel])	2.696	0.155	17.327	<0.001 ***
Voicing ([-voice] vs. [+voice])	0.466	0.151	3.077	<0.01 **
Tenseness (lax vs. tense)	0.868	0.176	4.928	<0.001 ***
Stress ([-stress] vs. [+stress])	0.139	0.224	0.624	0.532
Release * Voicing	-2.425	0.304	-7.978	<0.001 ***
Release * Tenseness	0.279	0.302	0.922	0.356
Voicing * Tenseness	-0.577	0.302	-1.908	0.056
Release * Voicing * Tenseness	0.024	0.605	0.040	0.968

Significant codes: <0.001 '***'; <0.01 '**'; <0.05 '*'; <0.1 '.'

The output of the third model given in Table 4.8 shows similar results to that of the first two models: there were significant main effects of Release ($z = 18.760$, $p < 0.001$), Voicing ($z = 3.358$, $p < 0.001$), and Tenseness ($z = 6.646$, $p < 0.001$), and there was a significant interaction of Release * Voicing ($z = -8.652$, $p < 0.001$). This model found a significant main effect of Place1 (labial vs. coronal) ($z = -4.986$, $p < 0.001$), which indicates that participants were more likely to categorize an English final stop as a stop followed by a vowel when the stop was coronal than when it was labial. However, the main effect of Place2 (coronal vs. dorsal) was only marginally significant ($p = 0.050$).[26] Thus, there was no significant effect of morphological alternation in the categorization task, which is consistent with the prediction of both the misperception and the perceptual similarity approaches. In addition, Tukey's HSD test of stop place showed that the difference between labial vs. dorsal final stops was significant ($p < 0.01$), indicating that dorsal final stops were more likely to be categorized as CV than labial final stops. This result is inconsistent with the prediction of the two approaches that there would be no effect of stop place in the task. This model also indicated that the interaction of Voicing * Tenseness was significant ($z = -2.061$, $p < 0.05$), suggesting that the effect of tense vowel depends on the voicing effect. I will discuss the unexpected place effect and the interaction of voicing and vowel tenseness in Section 4.1.5.

[26] Tukey's HSD test of stop place showed that the differences between coronal vs. dorsal final stops was not significant ($p = 0.123$).

Table 4.8. The output of Model.place

	Estimate	St. Error	z-value	Pr (>|z|)
(Intercept)	0.356	0.224	1.589	0.112
Release ([-rel] vs. [+rel])	2.697	0.143	18.760	<0.001 ***
Voicing ([-voice] vs. [+voice])	0.468	0.139	3.358	<0.001 ***
Tenseness (lax vs. tense)	0.927	0.139	6.646	<0.001 ***
Place1 (lab vs. cor)	-0.844	0.169	-4.986	<0.001 ***
Place2 (cor vs. dor)	0.329	0.168	1.956	0.050 .
Release * Voicing	-2.419	0.279	-8.652	<0.001 ***
Release * Tenseness	0.286	0.278	1.029	0.303
Voicing * Tenseness	-0.573	0.278	-2.061	<0.05 *
Release * Voicing * Tenseness	0.035	0.556	0.065	0.948

Significant codes: <0.001 ‘***’; <0.01 ‘**’; <0.05 ‘*’; <0.1 ‘.’

Table 4.9 gives the output of the last model where there were significant main effects of Release ($z = 17.358$, $p < 0.001$), Voicing ($z = 3.091$, $p < 0.01$), and Tenseness ($z = 2.681$, $p < 0.01$), and a significant interaction of Release * Voicing ($z = -7.985$, $p < 0.001$), as in all the other models. The main effect of Size was not significant ($p = 0.339$), indicating that participants were not significantly more likely to categorize an English final stop as CV when the form was monosyllabic than when it was polysyllabic.

Table 4.9. The output of Model.size

	Estimate	St. Error	z-value	Pr (>|z|)
(Intercept)	0.330	0.227	1.451	0.146
Release ([-rel] vs. [+rel])	2.695	0.155	17.358	<0.001 ***
Voicing ([-voice] vs. [+voice])	0.467	0.151	3.091	<0.01 **
Tenseness (lax vs. tense)	0.714	0.266	2.681	<0.01 **
Size (monosyllabic vs. polysyllabic)	0.261	0.274	0.954	0.339
Release * Voicing	-2.422	0.303	-7.985	<0.001 ***
Release * Tenseness	0.278	0.302	0.920	0.357
Voicing * Tenseness	-0.579	0.302	-1.920	0.054 .
Release * Voicing * Tenseness	0.019	0.603	0.032	0.974

Significant codes: <0.001 ‘***’; <0.01 ‘**’; <0.05 ‘*’; <0.1 ‘.’

In this section, the statistical analysis of the results showed that all the primary factors had significant main effects, i.e., stop release, stop voicing, and tenseness of pre-stop vowel; and that two interactions of those factors turned out to be significant, i.e., release * voicing and voicing * vowel tenseness. All four models had three different significant main effects and a significant interaction of release * voicing; the interaction of voicing * vowel tenseness was significant only in the model related to stop place. Among the three different extra factors (final stress, stop place, and word size), only stop place had a significant main effect in the categorization task.

4.1.4.3 Vowel-final words heard as consonant-final

This section discusses vowel-final English nonce words identified as consonant-final. As we have seen (Section 4.1.4.1), 6% of vowel-final words were identified as consonant-final, as opposed to 44% of consonant-final words (Table 4.3). Here we consider what could be special about the 6% of vowel-final words that were heard as consonant-final. The following possible factors were examined for vowel-final items heard as consonant-final: (i) onset voicing of final syllables, e.g., ˈkʰɛ.**tʰɨ** vs. ˈkʰɛ.**dɨ**; (ii) onset place of final syllables, e.g., ˈkʰɛ.**pʰɨ** vs. ˈkʰɛ.**tʰɨ** vs. ˈzai.**kʰɨ**; (iii) tenseness of penultimate vowel, e.g., ˈkʰ**ɛ**.tʰɨ vs. ˈv**u**ː.tʰɨ; (iv) stress of penultimate vowel, e.g., ˈgo.zɛ.tʰɨ vs. goˈ.zɛ.tʰɨ; and (v) word size, e.g., fɛ.gɨ vs. goˈ.zɛ.gɨ vs. ˌgo.moˈ.zɛ.gɨ. Stop release could not be considered since vowel-final words do not end in stops. The entire set of vowel-final items heard as consonant-final and their responses are given in Appendix 4.

Figure 4.5 shows how each attribute affected responses of vowel-final words.[27] Three main attributes are above chance level (Voiceless 67%, Lax 57%, Disyllabic 54%). The most frequent attribute is Voiceless (67%) and the least frequent one is Quadrisyllabic (22%). This result suggests that Korean speakers tended to be affected by Voicing, Vowel tenseness, and Word size when they heard vowel-final words. Of those three linguistic factors, Word size did not turn out to significantly affect the categorization of stop-final English nonce words. This could make sense in that perception of stop-final words as vowel-final and perception of vowel-final words as stop-final are completely opposite phenomena since the former involves hearing a vowel that is not present in the input and the latter involves failing to hear a vowel that is present in the input. The results suggest that Word size led to failure to hear a vowel in the

[27] Here, *attributes* refer to values of factors (predictors). That is, the predictor of Voicing has 2 attributes, Voiced and Voiceless. Similarly, the predictor of Place has 3 attributes, Labial, Coronal and Dorsal.

categorization of English vowel-final forms. Note that this factor did not contribute to the perception of an illusory vowel when Korean participants heard stop-final English forms. It is puzzling that Voicing and Vowel tenseness turned out to be a factor that favored Koreans both hearing an illusory vowel and failing to hear a vowel.

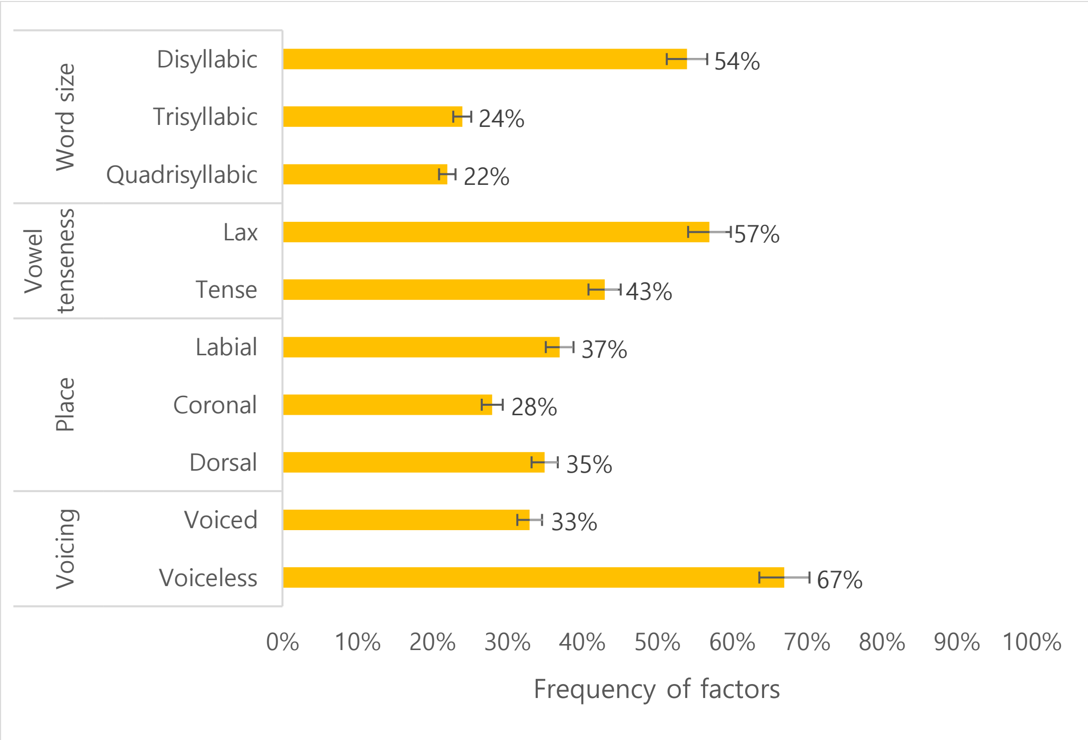

Figure 4.5. Attributes affecting responses of vowel-final items

Table 4.10 shows vowel-final words identified as consonant-final across participants. Out of thirty participants, P30 is considered an outlier (>Mean+2SD). As mentioned in Section 4.1.2, the results of this subject showed that he did not seem to understand the instructions for the experiment very well. When his results are removed from the data, we have better Mean and SD (Mean = 5.7%, SD = 12.9 → Mean = 3.7%, SD = 7%), as given in Table 4.10.

Table 4.10. Vowel-final items heard as consonant-final across participants

Participants	Number of 'word ends in consonant' response	'word ends in consonant' response (%)	
P1	1	1.5%	
P2	0	0%	
P3	0	0%	
P4	0	0%	
P5	1	1.5%	
P6	0	0%	
P7	2	3%	
P8	0	0%	
P9	1	1.5%	
P10	2	3%	
P11	3	4.5%	
P12	1	1.5%	
P13	0	0%	
P14	1	1.5%	
P15	1	1.5%	
P16	3	4.5%	
P17	17	25.8%	
P18	0	0%	
P19	2	3%	
P20	0	0%	
P21	8	12.1%	
P22	2	3%	
P23	1	1.5%	
P24	2	3%	
P25	0	0%	
P26	0	0%	
P27	19	28.8%	
P28	1	1.5%	
P29	3	4.5%	
P30	42	63.6%	after P30 is removed
	Mean	**5.7%**	**3.7%**
	SD	**12.9%**	**7%**

4.1.5 Discussion

We have looked at categorization choices in terms of each linguistic factor and different predictions of the two approaches. First, the adaptation-in-perception approach predicted that Korean participants would categorize English CVC as CVCV since they inaccurately hear an English final stop as being CV when the final stop is released or voiced, when it is preceded by a tense vowel, and when it occurs in a monosyllable. This approach predicted no significant effects in stop place and final stress because release of the final stop was controlled across each category of place and stress in the stimuli. This view also predicted no significant effect in morphological alternation since the final consonant of Korean nouns can surface as a coronal stop which means that Koreans would take English words ending in a coronal stop to be legal in Korean. On the other hand, the adaptation-in-production approach predicted that Korean participants would categorize English CVC as CVC since they accurately hear an English final stop as consonant-final. Thus, this approach predicted no significant effect of the given factors.

We found in the categorization task that stop release, stop voicing, vowel tenseness, and stop place had significant effects: a greater likelihood of vowel-final responses was more likely after (i) released stops than unreleased stops, (ii) voiced stops than voiceless stops, (iii) stops following a tense vowel than following a lax vowel, and (iv) dorsal stops than labial stops. The effects of release, voicing, and vowel tenseness are consistent with the adaptation-in-perception approach, but the stop place effect is consistent with neither the adaptation-in-perception nor the adaptation-in-production approach. No effect was found in the other factors in the categorization task: no effect of final stress and morphological alternation is consistent with both approaches, and no effect of word size is consistent with the adaptation-in-production approach. Thus, the predictions of the categorization experiment clearly support the adaptation-in-perception approach.

All in all, in the categorization experiment, we saw that four factors played a role: an English final stop was more likely to be categorized as a stop followed by a vowel when the stop was released, when it was voiced, when it was preceded by a tense vowel, and when it was dorsal. In addition, the interaction of release and voicing and the interaction of voicing and vowel tenseness were significant. Below I discuss the place effect and then turn to the interaction of voicing and vowel tenseness.

Place effect

We have seen that there was a significant stop place effect in the categorization task ($p < 0.01$). As shown in Figure 4.6, Korean participants were more likely to categorize an English final stop as a stop followed by a vowel when the stop was dorsal than when it was labial.

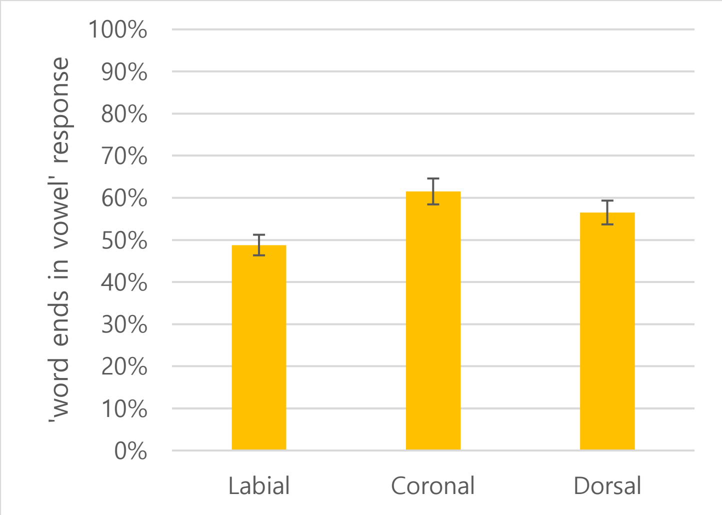

Figure 4.6. Categorization choices by place of the final stop (Error bars indicate 95% Confidence Intervals)

According to Kang 2003, the more likely a final stop is to be released by English speakers, the more likely it is to undergo vowel insertion by Korean speakers, so vowel insertion is more likely after a dorsal final stop than after a labial final stop because Korean speakers are more likely to hear a released pronunciation of a dorsal final stop than that of a labial final stop. Thus, there is nothing about dorsality itself that can contribute to vowel insertion. The only reason labial vs. dorsal stops matters is because it affects the likelihood of release in English pronunciation. However, here in the categorization task, participants were not hearing naturalistic spoken English. They were hearing stimuli where stop release was strictly balanced across places of articulations; participants listened to the same numbers of released and unreleased stops for each category of place. Thus, unlike in naturalistic English, stop place was completely independent of stop release in the current experiment. For this reason, neither approach predicted a greater likelihood of vowel-final responses as a consequence of final consonant place.

However, this prediction was not confirmed in the task; the results indicated that dorsal final stops were significantly more likely to be categorized as CV than labial final stops. This unpredicted finding regarding stop place effect might be attributed to the fact that dorsal codas have longer release bursts than labial codas (mean release duration: 24ms vs. 13ms), as discussed in 2.3.2.1. Previous studies report that dorsal final stops have the longest release bursts and that longer release bursts are more likely to be heard as having an epenthetic vowel

(Byrd 1993; Wilson et al. 2014). Hence, the longer release bursts of dorsal stops as compared to labial stops might be a motivation for the higher rate of vowel-final responses after dorsal stops in the task.

Interaction of voicing and vowel tenseness

We have seen that there was a significant interaction of stop voicing and tenseness of the pre-stop vowel in the task. As shown in Table 4.11, Tukey's HSD post-hoc comparisons of the interaction of Voicing * Tenseness confirmed that the vowel tenseness effect was significant only for the voiceless condition (see Figure 4.7): tense pre-stop vowels triggered more vowel-final responses than lax pre-stop vowels when stop voicing was absent ($z = 2.599$, $p < 0.05$) whereas the difference between lax vs. tense conditions was not significant when the final stop was voiced ($p = 0.413$).

Table 4.11. Pairwise comparisons: results from Tukey HSD post-hoc analyses on the model of interaction of Voicing * Tenseness

Comparisons	**Estimate**	**St. Error**	**z-value**	**Pr (>|z|)**
voiced:lax – voiceless:lax	0.746	0.454	1.642	0.354
voiceless:tense – voiceless:lax	1.143	0.440	2.599	<0.05 *
voiced:tense – voiced:lax	0.666	0.433	1.539	0.413
voiced:tense – voiceless:tense	0.026	0.417	0.646	0.916

Significant codes: <0.001 '***'; <0.01 '**'; <0.05 '*'; <0.1 '.'

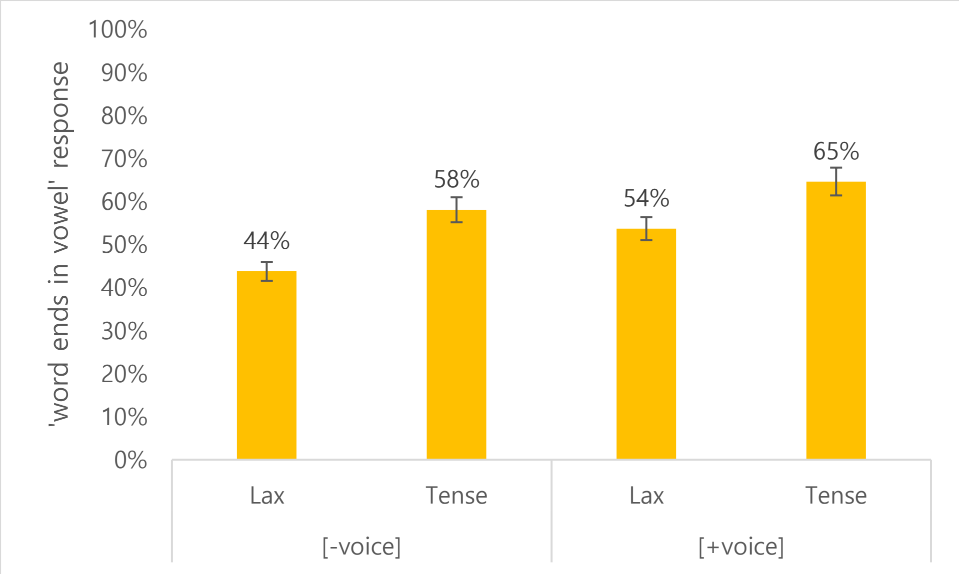

Figure 4.7. Categorization choices by voicing and vowel tenseness (Error bars indicate 95% confidence intervals)

It is not so clear in Figure 4.7 that the tense vowel effect was significant only for voiceless stops since the difference between lax vs. tense items looks very similar for both stop voicing conditions. The significant interaction of voicing and vowel tenseness might be affected by stop place because this was found only in the model involving stop place. Figure 4.8 summarizes categorization choices by voicing and place of final stops and vowel tenseness, where only forms ending in labial stops in tense items show a different pattern, i.e., voiceless stops had a higher rate of vowel-final responses than voiced stops, whereas all the other bars of voiced vs. voiceless stops show an opposite direction, with more voiced stops categorized as CV.

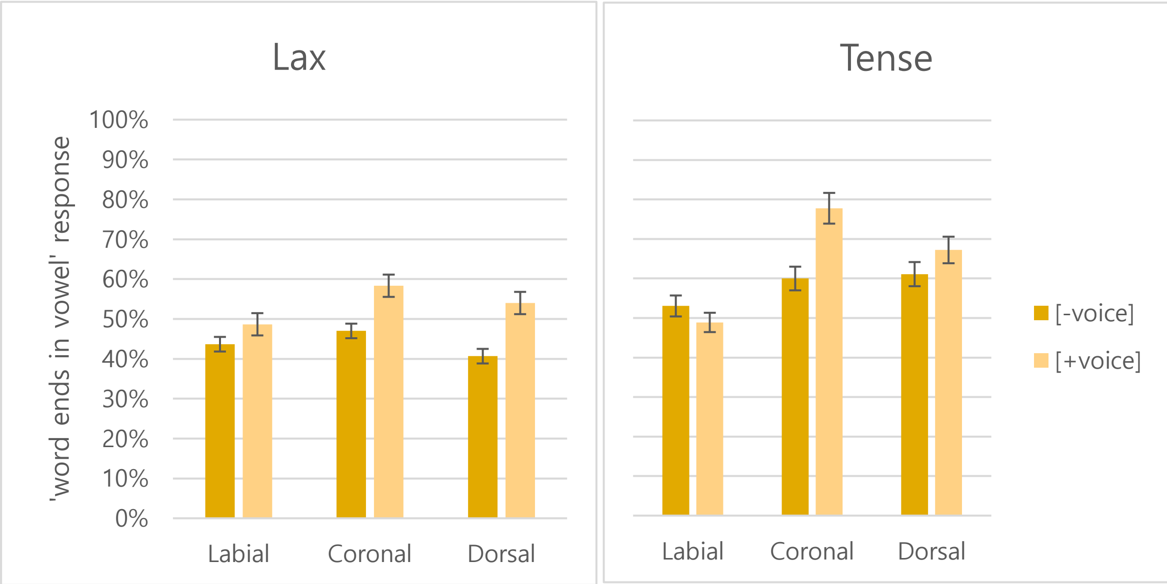

Figure 4.8. Categorization choices by voicing and place of the final stop in lax vs. tense items (Error bars indicate 95% confidence intervals)

Thus, it is possible that the difference between voiced vs. voiceless stops shown in tense labial items affected the significant interaction of stop voicing and vowel tenseness. However, it is not so obvious why only tense labial items had a different pattern since the measurement of the stimuli showed that the release burst duration of labial stops was the same for voiced and voiceless stops (13ms for both voiced and voiceless stops). It is strange that the voicing effect of tense labial items went in the unpredicted direction because there does not seem to be a factor that could contribute to the likelihood of vowel-final responses in voiceless more than in voiced stops.

Vowel tenseness effect

We have seen that there was a significant effect of tense pre-stop vowel in the categorization task ($p < 0.001$). Korean participants were more likely to categorize an English final stop as a stop followed by a vowel when the pre-stop vowel was tense than when it was lax. The comparison between lax vs. tense vowels might be affected by the fact that Korean speakers tend to analyze diphthongs (tense vowels) as two syllables. A better comparison therefore might focus only on monophthongal items: lax vs. tense monophthong items. Table

4.12 compares consonant-final vs. vowel-final responses for lax vs. tense monophthong items: for the total number of forms with monophthong pre-stop vowels (lax 1800 + tense monophthong 720 = 2520), 49% of the forms with lax vowels were identified as vowel-final, while 54% of the forms with tense monophthong vowels were identified as vowel-final.

Table 4.12. Consonant-final vs. vowel-final responses: vowel tenseness

Vowel tenseness	C-final responses	V-final responses	C-final responses	V-final responses
Lax (e.g., [ɛ])	923	877	51%	49%
Tense monophthong (e.g., [i:], [u:])	330	390	46%	54%

Post-hoc comparisons of vowel tenseness indicated that the difference between lax vs. tense monophthong items was only marginally significant ($p = 0.078$). Measurements of the stimuli of the current study revealed that lax pre-final vowels were longer than tense pre-final vowels (mean vowel duration: 145ms vs. 101ms), which might be a possible reason for the relatively low rate of vowel-final responses after tense monophthong vowels.

So far, we have seen results from two perception experiments. As discussed in Chapter 3, the results of the syllable counting experiment showed that two factors of release and vowel tenseness led to a greater likelihood of the perception of an illusory vowel. In this chapter, the results of the categorization experiment showed that four factors increased the likelihood that an English final stop would be categorized as a stop followed by a vowel. In the following chapter, I will report on a similarity judgment experiment designed to examine how much vowel insertion reflects misperception and which factors are most associated with misperception.

Chapter 5
Similarity Judgments

Results from the categorization experiment showed that Korean speakers were more likely to categorize English stop-final forms as vowel-final when the final stop was released, when it was voiced, when it was preceded by a tense vowel, and when it was dorsal. In this chapter, I report on a similarity judgement experiment designed to investigate how Korean participants judged stop-final forms in a forced choice task in which they were asked whether the form sounded more similar to a Korean stop-final form or to a Korean vowel-final form. This experiment is different from the syllable counting task and the categorization task in that it is more directly related to conscious judgments of perceptual similarity rather than direct perception.

5.1 Similarity judgment experiment

The similarity judgement experiment was designed to test the effects of the same linguistic factors that were considered in the syllable counting task and the categorization task. This experiment investigated whether an English final stop sounds similar to a stop followed by a vowel to Korean participants when specific phonetic characteristics are present. In contrast to the categorization task, which asked for the analysis of a structure, the similarity judgement task just asked about similarity; participants were asked to decide whether a form containing an English final released stop sounded similar to a form containing a stop plus vowel.

5.1.1 Participants

Thirty Korean native speakers who were undergraduate and graduate students at Sogang University in Seoul, South Korea participated in the similarity judgement task. This group was different from those who participated in the syllable counting task and the categorization task. The participants, 12 male and 18 female, ranged in age from 20 to 29, with an average age of 26.8 at the time of participation (SD=11.6). The average age of first exposure to English study was 10.2 years (SD=1.4). No participants were English majors or had lived in an English-speaking country at the time of the experiment. No participants reported any speech or hearing disorders. All participants volunteered to participate in the experiment and were paid a monetary compensation upon completing the task.

5.1.2 Stimuli and procedure

The 30 Korean participants each listened to 132 sets of auditory target items. Each set consisted of 3 forms, in the following order: a Korean nonce form, an English nonce form, and a second Korean nonce form (e.g., Korean [k^{h}ɛt˺] -- English [k^{h}ɛt] -- Korean [k^{h}ɛt^{h}ɨ]). The English nonce form was recorded by an English native speaker, and the first and third forms were recorded by a Korean native speaker. All the English non-words ended in a stop; one of the Korean non-words ended in a consonant and the other Korean non-word ended in a lexical final vowel. The number of English nonce words was 132 and the number of Korean nonce words (A+B) was 81 (A+B=27+54).[28] The set of stimuli including filler items is provided in Appendix 5.

The participants were asked to decide whether the second word sounded more similar to the first word or to the third word for each set. They had to choose one of the forms as most similar. Every set was presented in a randomized order for each subject. The order of the two types of Korean forms, CVC and CVCV, was also randomized for each participant. Participants listened to the stimuli through a laptop computer using a headphone in a sound-attenuated room in the English Department at Sogang University. Participants had a short practice round before the actual task.

Praat's ExperimentMFC was used in this experiment. Participants saw three buttons, labelled *first*, *second*, and *third*, but the second button was not clickable, as shown in Figure

[28] The number of English stimuli does not match that of Korean stimuli due to the following reasons: first, since Korean final stops do not have a release burst, the Korean stimuli corresponding to English stimuli ending in either a released or an unreleased stop had either an unreleased coda or a released onset followed by a vowel. For example, two English stimuli [k^{h}ɛt^{h}] and [k^{h}ɛt˺] corresponded to either [k^{h}ɛt˺] or [k^{h}ɛt^{h}ɨ] in Korean. Second, since voicing is not a contrastive feature and voiced stops occur only between sonorants in Korean, English stimuli such as [k^{h}ɛd^{h}] and [k^{h}ɛd˺] corresponded to either [k^{h}ɛt˺] or [k^{h}ɛdɨ] in Korean. Third, Korean does not allow lexical stress, and thus English stimuli such as [ˈgozɛt˺] and [goˈzɛt˺] corresponded to either [gozɛt˺] or [gozɛt^{h}ɨ] in Korean.

5.1.

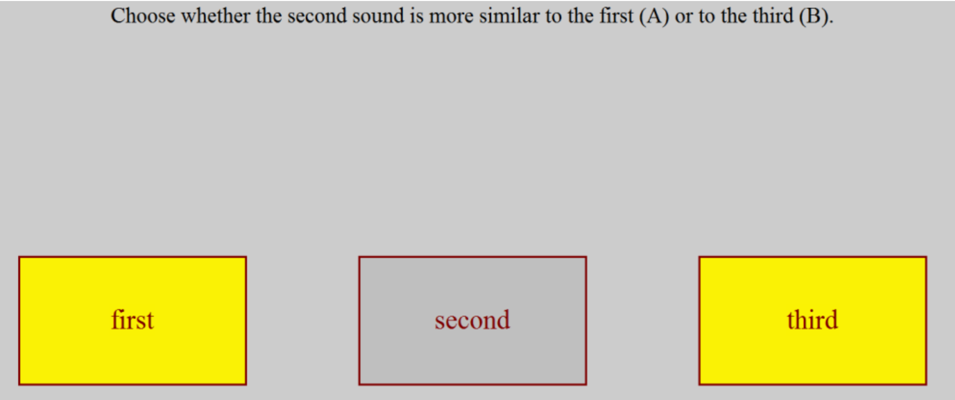

Figure 5.1. Response screen for the similarity judgment experiment

A new stimulus was presented as soon as participants made their choice. Listeners heard each stimulus only once and could not go back to listen again. Participants heard 142 different sets of stimuli including fillers, so they clicked 142 times. The inter-stimulus interval was 0.3 seconds, and participants had a short break after every 44 trials. This task took about 15 minutes to complete.

5.1.3 Predictions

Table 5.1 shows the predictions of the adaptation-in-production approach, which assumes accurate perception. According to this approach, even when Korean listeners accurately perceive the English form as consonant-final, they insert a vowel in their production in order to maintain perceptual similarity to an English final released or voiced stop. This predicts that the listeners will judge an English CVC form ending in a released or voiced stop as more similar to Korean CVC than Korean CVCV. Similarly, an English CVC form preceded by a tense vowel is likely to be judged by Korean listeners as more similar to Korean CVCV than CVC, since vowels are longer in open syllables in Korean and inserting a vowel after a form with a tense vowel would maintain the perceptual similarity in vowel length. However, this approach predicts no significant effects of stop place, final stress, final [t], and word size because these factors alone are not associated with acoustic cues that increase perceptual similarity to CVCV—although, as pointed out by Kang (2003), some of these factors are associated in

English with greater likelihood of release, in these stimuli release was strictly controlled to eliminate any correlation between release and other factors.

Table 5.1. Predictions of the adaptation-in-production approach for similarity judgments

Linguistic factors		**Predictions**
Primary factors (factors related to perceptual similarity of C and CV)	**Stop release**	An English word ending in a released stop will be more likely to be judged as similar to a Korean vowel-final word than an English word ending in an unreleased stop.
	Stop voicing	An English word ending in a voiced stop will be more likely to be judged as similar to a Korean vowel-final word than an English word ending in a voiceless stop.
	Vowel tenseness	An English word will be more likely to be judged as similar to a Korean vowel-final word when the English vowel preceding the final stop is tense than when it is lax.
Secondary factors (factors related to release in English)	**Stop place (labials vs. dorsals)**	There will be no significant difference in the similarity judgment between an English word ending in a labial stop and a word ending in a dorsal stop.
	Final stress	There will be no significant difference in the similarity judgment between an English word with a stressed final syllable and a word with an unstressed final syllable.
Other factors	**Morphological alternation (coronals)**	There will be no significant difference in the similarity judgment between an English word ending in a coronal stop and a word ending in a labial or dorsal stop.
	Word size (phonological markedness)	There will be no significant difference in the similarity judgment between an English monosyllabic word and an English polysyllabic word.

The predictions of the adaptation-in-perception approach, shown in Table 5.2, match those of the adaptation-in-production approach for release, voicing, vowel tenseness, place, stress and morphological alternation. First, release and voicing are expected to cause Korean listeners to hear an illusory vowel, and thus Korean listeners are expected to judge that Korean CVCV is most similar to English CVC when the English final stop is released or voiced. Next, vowel tenseness will cause the perception of an illusory vowel as a perceptually based factor, and hence the Korean participants will judge that Korean CVCV is more similar to English CVC than Korean CVC when the English final stop is preceded by a tense vowel. Last, there is expected to be no significant effects of stop place, final stress, and morphological alternation. All of these predictions about release, voicing, vowel tenseness, place, stress, and morphological alternation are the same as the predictions made by the accurate perception approach for the same reasons as in that approach.

However, the status of word size in the adaptation-in-perception approach is less clear since it is plausible that the dispreference for monosyllables could bias Korean listeners toward hearing an extra syllable in English monosyllabic forms. Thus, Korean participants might be expected to judge that English CVC is more similar to Korean CVCV than to Korean CVC when the English final stop occurs in monosyllables.

Table 5.2. Predictions of the adaptation-in-perception approach for similarity judgments

Linguistic factors		**Predictions**
Primary Factors (factors related to perception of an illusory vowel)	**Stop release**	An English word ending in a released stop will be more likely to be judged as similar to a Korean vowel-final word than an English word ending in an unreleased stop.
	Stop voicing	An English word ending in a voiced stop will be more likely to be judged as similar to a Korean vowel-final word than an English word ending in a voiceless stop.
	Vowel tenseness	An English word will be more likely to be judged as similar to a Korean vowel-final word when the English vowel preceding the final stop is tense than when it is lax.
Secondary factors (factors related to release in English)	**Stop place (labials vs. dorsals)**	There will be no significant difference in the similarity judgment between an English word ending in a labial stop and a word ending in a dorsal stop.
	Final stress	There will be no significant difference in the similarity judgment between an English word with a stressed final syllable and a word with an unstressed final syllable.
Other factors	**Morphological alternation (coronals)**	There will be no significant difference in the similarity judgment between an English word ending in a coronal stop and a word ending in a labial or dorsal stop.
	Word size (phonological markedness)	An English word will be more likely to be judged as similar to a Korean vowel-final word when the English word is monosyllabic than when it is polysyllabic.

We have six factors where the two hypotheses make similar predictions, i.e., release, voicing, vowel tenseness, place, stress, and morphological alternations, and only one factor where might they make conflicting predictions, i.e., word size.

5.1.4 Results

The results from the similarity judgment experiment indicated that Korean participants were more likely to judge an English final stop as similar to a stop plus vowel (i) when the final stop was released than when it was unreleased, (ii) when it was preceded by a tense vowel than when it was preceded by a lax vowel, (iii) when it was dorsal than when it was labial, and (iv) when it occurred in a monosyllable than when it occurred in a polysyllable. Figure 5.2 visually summarizes the effects of release and vowel tenseness, which were found in all the statistical models built for the task except in the model involving word size where there was no vowel tenseness effect (See Tables 5.4, 5.6 & 5.7). Tukey's HSD test of stop place confirmed that there was a place effect, and the model involving word size found a significant effect of word length (see Figure 5.6). Also, the interaction of release and voicing was significant in all four models, indicating that vowel insertion was more likely when the English final stop was unreleased voiced than when it was unreleased voiceless, and when it was released voiceless than when it was released voiced (see Table 5.5).

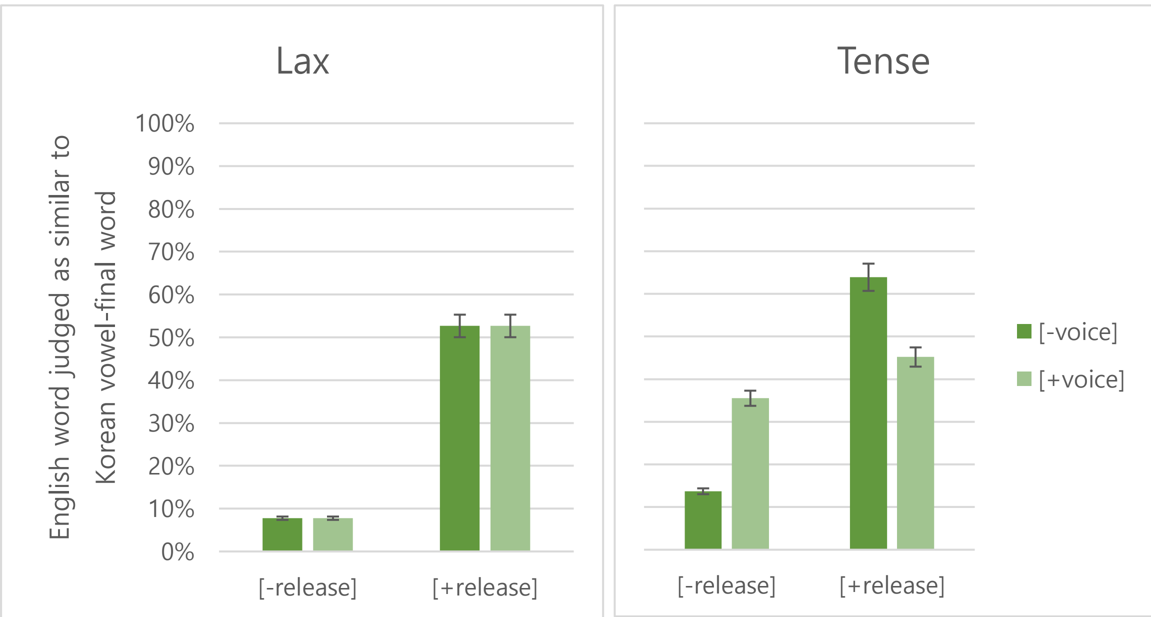

Figure 5.2. Similarity judgment choices by release and voicing in forms with lax vs. tense vowels (Error bars indicate 95% confidence intervals)

The presence/absence of an epenthetic vowel reflected in the choice of responses was modeled using a series of mixed effects logistics regression models, implemented in the *lme4* package (Bates et al. 2015) in R (R Development Core Team 2016). I built the first model for the three acoustic factors (release, voicing, and vowel tenseness), and then three additional models were built by adding each of the other factors (stress, place, and size) to the first model (see Table 5.3). For all of the models, the dependent variable was the participants' answers (whether participants' response was Korean consonant-final or Korean vowel-final), and it was coded as 0 for responses of 'English word judged as similar to Korean consonant-final word' and 1 for responses of 'English word judged as similar to Korean vowel-final word'.

Fixed effects included six factors, release (unreleased or released), voicing (voiceless or voiced), vowel tenseness (lax or tense), stress of final syllable (unstressed or stressed), stop place (labial, coronal or dorsal), and word size (monosyllabic or polysyllabic). Interactions of the acoustic factors (release, voicing, and vowel tenseness) were also included in all of the models. Predictors including Release, Voicing, Tenseness, Stress, and Size were deviation-coded, and Place was coded using forward difference coding. Random effects included participants and items; random intercept model converged and only a random intercept was included for both participants and items. Follow up post-hoc comparisons were conducted using Tukey's HSD tests of *multcomp* package (Hothorn et al. 2008). The four regression models are given in Table 5.3 and their outputs are summarized in Tables 5.4, 5.6, 5.7, and 5.8.

Table 5.3. Models for the similarity judgment task

Model.basic	glmer (Response ~ RELEASE * VOICING * TENSENESS + (1|subject) + (1|item), data = Syllable, family="binomial")
Model.stress	glmer (Response ~ RELEASE * VOICING * TENSENESS + STRESS + (1|subject) + (1|item), data = Syllable, family="binomial")
Model.place	glmer (Response ~ RELEASE * VOICING * TENSENESS + PLACE + (1|subject) + (1|item), data = Syllable, family="binomial")
Model.size	glmer (Response ~ RELEASE * VOICING * TENSENESS + SIZE + (1|subject) + (1|item), data = Syllable, family="binomial")

The output of the first model is given in Table 5.4, where a main effect of Release was significant ($z = 10.006$, $p < 0.001$); Korean participants were more likely to judge an English final stop as similar to a stop followed by a vowel when the final stop was released than when it was unreleased. This result is consistent with the prediction of both the adaptation-in-production and the adaptation-in-perception approaches.

Table 5.4. The output of Model.basic

	Estimate	St. Error	z-value	Pr (>|z|)
(Intercept)	-1.012	0.189	-5.340	<0.001 ***
Release ([-rel] vs. [+rel])	1.847	0.184	10.006	<0.001 ***
Voicing ([-voice] vs. [+voice])	0.225	0.182	1.232	0.224
Tenseness (lax vs. tense)	0.723	0.183	3.952	<0.001 ***
Release * Voicing	-2.494	0.366	-6.800	<0.001 ***
Release * Tenseness	-0.226	0.365	-0.620	0.535
Voicing * Tenseness	-0.103	0.365	-0.284	0.777
Release * Voicing * Tenseness	0.227	0.731	0.310	0.756

Significant codes: <0.001 '***'; <0.01 '**'; <0.05 '*'; <0.1 '.'

This model given in Table 5.4 also found a significant main effect of Tenseness ($z = 3.952$, $p < 0.001$). Figure 5.3 shows the difference between forms with lax vs. tense vowels; an English final stop was more likely to be judged as similar to a stop followed by a vowel when the vowel preceding the final stop was tense than when it was lax. I will discuss the difference between items with lax pre-stop vowels and items with tense monophthongs in Section 5.1.5.

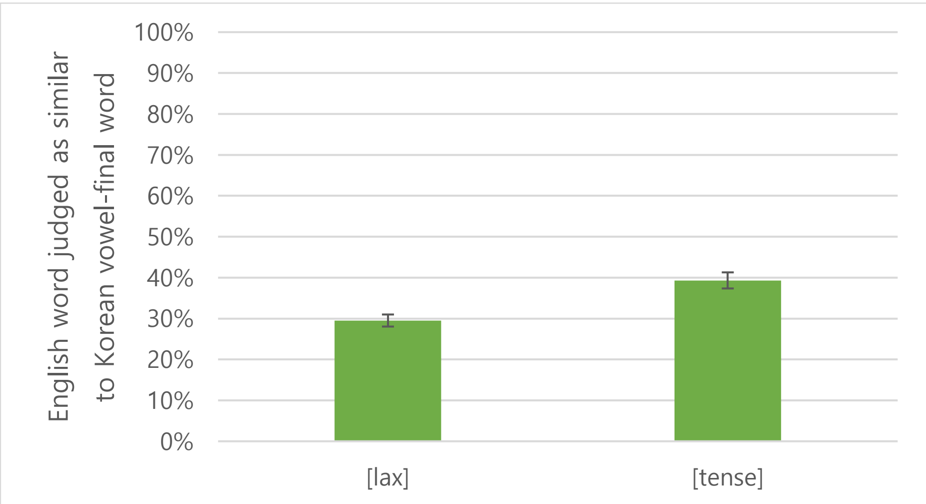

Figure 5.3. Similarity judgment choices by vowel tenseness preceding the final stop (Error bars indicate 95% confidence intervals)

In the first model given in Table 5.4, Voicing did not have a significant main effect ($p = 0.224$), but there was a significant interaction between Release * Voicing ($z = -6.800$, $p < 0.001$). Figure 5.4 shows similarity judgment choices based on release and voicing of the English final stop. Although there was no significant main effect of voicing in the first model above, as shown in Figure 5.4, when final stops were separated into released and unreleased, we see a voicing effect in both release conditions: a predicted direction of voicing effect in unreleased stops and an opposite direction of voicing effect in released stops. As shown in Table 5.5, Tukey's HSD post-hoc comparisons of Release * Voicing interaction confirmed that voiced stops induced more vowel-final responses than voiceless stops did when release was absent ($z = 5.189$, $p < 0.001$) whereas voiceless stops had higher rate of vowel-final responses in released stops ($z = -3.918$, $p < 0.001$). In addition, in Figure 5.4, although it appears that release makes a CV percept more likely for both voiceless and voiced stops, the results of the pairwise comparisons given in Table 5.5 indicated that released stops induced more CV response than unreleased stops when voicing was absent ($z = 11.018$, $p < 0.001$) whereas the differences between unreleased and released stops were not significant when the stop was voiced ($p = 0.106$).

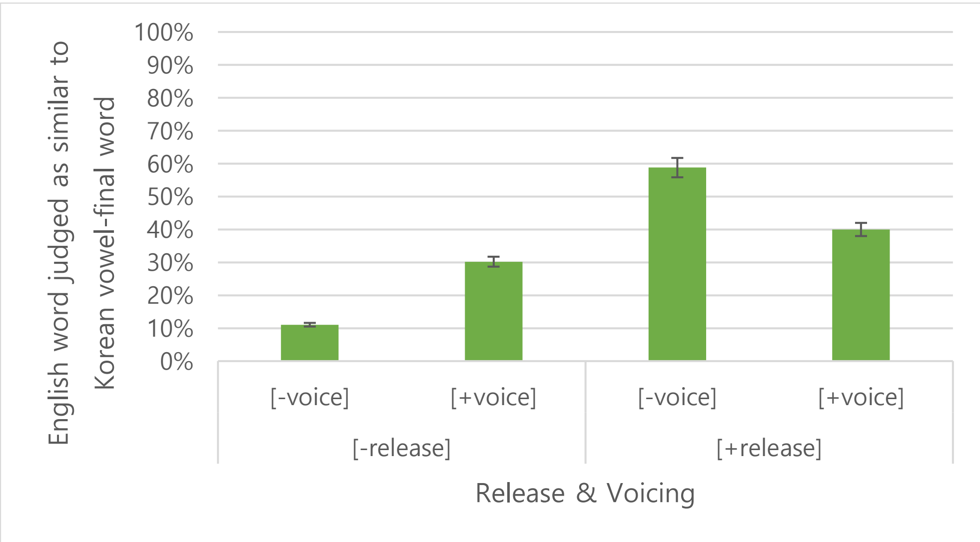

Figure 5.4. Similarity judgment choices by release and voicing of the final stop (Error bars indicate 95% confidence intervals)

Table 5.5. Pairwise comparisons: results from Tukey HSD post-hoc analyses on the model of interaction of release * voicing

Comparisons	Estimate	St. Error	z-value	Pr (>|z|)
[+rel]:[-voice] – [-rel]:[-voice]	3.052	0.277	11.018	<0.001 ***
[-rel]:[+voice] – [-rel]:[-voice]	1.435	0.276	5.189	<0.001 ***
[+rel]:[+voice] – [+rel]:[-voice]	-1.020	0.260	-3.918	<0.001 ***
[+rel]:[+voice] – [-rel]:[+voice]	0.595	0.262	2.268	0.106

Significant codes: <0.001 '***'; <0.01 '**'; <0.05 '*'; <0.1 '.'

Since both release and voicing of the final stop were predicted by the two approaches to lead to more frequent vowel-final responses, the highest rate of vowel-final responses was expected to occur in forms ending in a released voiced stop, and the lowest rate of vowel-final responses in forms ending in an unreleased voiceless stop. However, while forms ending in unreleased voiceless stops did have the lowest rate, forms ending in released voiced stops actually had a lower rate than forms ending in released voiceless stops.

The second model in Table 5.6 found significant main effects of Release ($z = 10.040$, $p < 0.001$) and Tenseness ($z = 2.874$, $p < 0.01$), and a significant interaction of Release * Voicing ($z = -6.825$, $p < 0.001$), as in the first model. Voicing and Stress did not have a significant main effect in this model (Voicing: $p = 0.224$; Stress: $p = 0.338$).

Table 5.6. The output of Model.stress

	Estimate	St. Error	z-value	Pr (>|z|)
(Intercept)	-1.089	0.206	-5.285	<0.001 ***
Release ([-rel] vs. [+rel])	1.842	0.183	10.040	<0.001 ***
Voicing ([-voice] vs. [+voice])	0.220	0.181	1.216	0.224
Tenseness (lax vs. tense)	0.614	0.213	2.874	<0.01 **
Stress ([-stress] vs. [+stress])	0.263	0.275	0.957	0.338
Release * Voicing	-2.487	0.364	-6.825	<0.001 ***
Release * Tenseness	-0.217	0.363	-0.599	0.549
Voicing * Tenseness	-0.094	0.363	-0.259	0.795
Release * Voicing * Tenseness	0.215	0.726	0.297	0.766

Significant codes: <0.001 '***'; <0.01 '**'; <0.05 '*'; <0.1 '.'

The output of the third model given in Table 5.7 shows the same results as in the first two models: there were significant main effects of Release ($z = 10.692$, $p < 0.001$) and Tenseness ($z = 4.165$, $p < 0.001$); the interaction of Release * Voicing was significant ($z = -7.214$, $p < 0.001$). There was no significant main effect of Voicing ($p = 0.202$) just like in the models seen above.

Table 5.7. The output of Model.place

	Estimate	St. Error	z-value	Pr (>|z|)
(Intercept)	-1.012	0.186	-5.426	<0.001 ***
Release ([-rel] vs. [+rel])	1.845	0.172	10.692	<0.001 ***
Voicing ([-voice] vs. [+voice])	0.217	0.170	1.274	0.202
Tenseness (lax vs. tense)	0.712	0.171	4.165	<0.001 ***
Place1 (lab vs. cor)	-0.898	0.206	-4.345	<0.001 ***
Place2 (cor vs. dor)	0.346	0.203	1.707	0.087 .
Release * Voicing	-2.472	0.342	-7.214	<0.001 ***
Release * Tenseness	-0.216	0.341	-0.633	0.526
Voicing * Tenseness	-0.085	0.341	-0.251	0.801
Release * Voicing * Tenseness	0.187	0.682	0.275	0.783

Significant codes: <0.001 '***'; <0.01 '**'; <0.05 '*'; <0.1 '.'

In this model given in Table 5.7, the main effect of Place1 (labial vs. coronal) was significant ($z = -4.345$, $p < 0.001$), indicating that participants were more likely to judge an English final stop as similar to a Korean vowel-final word when the stop was coronal than when it was labial (see Figure 5.5); yet, the main effect of Place2 (coronal vs. dorsal) was marginally significant ($p = 0.087$).[29] Thus, there was no significant effect of morphological alternation in the similarity judgement task, which is consistent with the prediction of the two approaches. Also, Tukey's HSD test of stop place showed that the difference between labial vs. dorsal final stops was significant ($p < 0.05$); dorsal final stops were more likely to be judged as similar to Korean vowel-final than labial final stops. This result is inconsistent with the prediction of the two approaches that there would be no stop place effect in the task.

[29] Tukey's HSD test of stop place indicated that the relationship between coronal vs. dorsal final stops was not significant ($p = 0.202$).

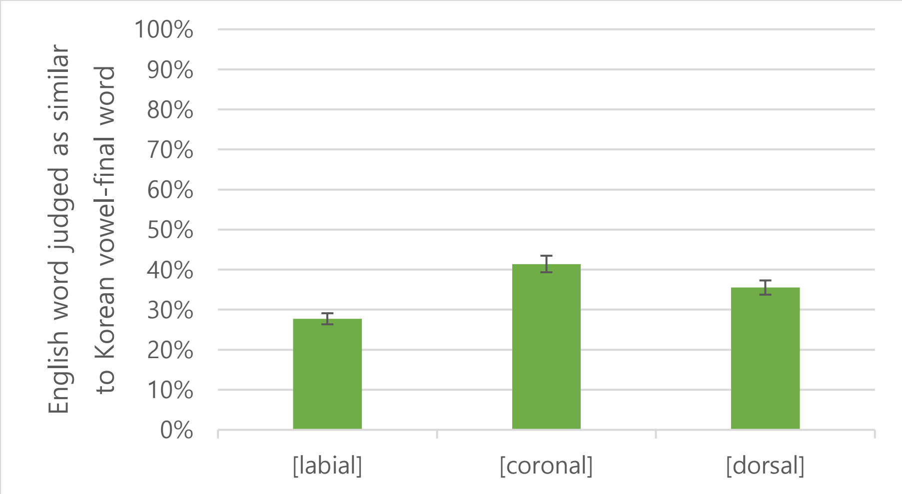

Figure 5.5. Similarity judgement choices by place of the final stop (Error bars indicate 95% confidence intervals)

Table 5.8 gives the output of the final model where there was a significant main effect of Release ($z = 10.285$, $p < 0.001$) and a significant interaction of Release * Voicing ($z = -6.982$, $p < 0.001$), just like in all the other models seen above. However, unlike the other models, this model had no significant main effect of Tenseness ($p = 0.816$), which is possibly because vowel tenseness and word size could be confounded, i.e., tense vowels were included only in monosyllabic items in the stimuli.

Table 5.8. The output of Model.size

	Estimate	St. Error	z-value	Pr (>|z|)
(Intercept)	-1.091	0.191	-5.201	<0.001 ***
Release ([-rel] vs. [+rel])	1.843	0.179	10.285	<0.001 ***
Voicing ([-voice] vs. [+voice])	0.225	0.177	1.254	0.204
Tenseness (lax vs. tense)	0.072	0.313	0.232	0.816
Size (monosyllabic vs. polysyllabic)	-0.814	0.326	-2.494	<0.05 *
Release * Voicing	-2.492	0.356	-6.982	<0.001 ***
Release * Tenseness	-0.226	0.355	-0.636	0.524
Voicing * Tenseness	-0.102	0.355	-0.288	0.773
Release * Voicing * Tenseness	0.233	0.711	0.328	0.742

Significant codes: <0.001 ‘***’; <0.01 ‘**’; <0.05 ‘*’; <0.1 ‘.’

In this model, the main effect of Size was significant ($z = -2.494$, $p < 0.05$), indicating that participants were more likely to judge an English final stop as similar to a Korean vowel-final word when the English form was monosyllabic than when it was polysyllabic, which is shown in Figure 5.6. The size effect is different from the effects of acoustic factors since word size is a statistical preference. I will have a detailed discussion about this effect in Section 5.1.5.

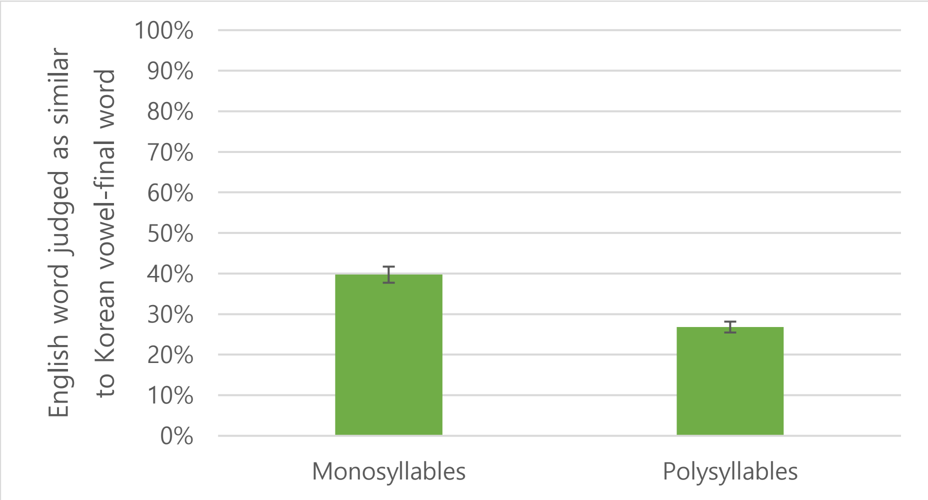

Figure 5.6. Similarity judgement choices by word size (Error bars indicate 95% confidence intervals)

In this section, the statistical analysis of the results showed that there were significant main effects of stop release and tenseness of pre-final vowel. Also, the interaction of release * voicing was significant. All four models found a significant main effect of vowel tenseness except for the model related to word size. Among the three different extra factors (final stress, stop place, and word size), stop place and word size had a significant main effect for the similarity judgment task.

5.1.5 Discussion

In this chapter, we looked at similarity judgment choices in terms of each linguistic factor and different predictions of the two approaches. First, the adaptation-in-perception approach predicted that participants would choose Korean CVCV as more similar to English CVC than Korean CVC since they inaccurately hear an English final stop as being CV when the stop is released or voiced, when it is preceded by a tense vowel, and when it occurs in a monosyllable. This approach predicted no significant effects in stop place, final stress, and morphological alternation because release was balanced across each category of place and stress in the stimuli or because Korean nouns can end in coronal stops so that there is no reason to make Koreans think that English words cannot end in coronal stops. On the other hand, the adaptation-in-production approach predicted that Korean CVCV would be judged as more similar to English CVC than Korean CVC due to the phonetic similarity between English and Korean forms although participants accurately perceive English CVC. This approach made the same predictions as the adaptation-in-perception approach for release, voicing, vowel tenseness, place, stress, and morphological alternation for the same reasons as in that approach, and a different prediction for word size: participants would choose Korean CVCV as more similar to English CVC than Korean CVC when the English final stop is released or voiced, and when it is preceded by a tense vowel, while there would be no significant effect of place, stress, morphological alternation, and word size.

We found in the similarity judgment task that stop release, vowel tenseness, stop place, and word size had significant effects: a greater likelihood of vowel-final responses was more likely after (i) released stops than unreleased stops, (ii) stops following a tense vowel than following a lax vowel, (iii) dorsal stops than labial stops, and (iv) monosyllabic forms than polysyllabic forms. The effects of release, vowel tenseness, and word size are consistent with both the adaptation-in-perception and the adaptation-in-production approaches, but the stop place effect and no voicing effect are consistent with neither of the two approaches. No effect of final stress and morphological alternation is consistent with both approaches. Thus, the predictions of the categorization experiment seem to support the adaptation-in-perception approach although it is plausible that the adaptation-in-production approach was playing a role.

All in all, in the similarity judgment experiment, we saw that four factors played a role: an English final stop was more likely to be categorized as a stop followed by a vowel when the stop was released, when it was preceded by a tense vowel, when it was dorsal, and when it occurred in a monosyllable. In addition, the interaction of release and voicing was significant. Below I will discuss the effect of word length and then turn to the vowel tenseness effect.

Word size effect

Here, I address the question of why monosyllabic words had more frequent vowel-final responses than polysyllabic words, which was found in the last model discussed in the preceding section (Table 5.8, Figure 5.6). Hirano (1994b) argues that a possible reason why Korean adapts many English monosyllabic words as disyllabic forms is that Korean prefers disyllabic prosodic word structure. As discussed in Hirano (1994a), only 0.76% of words in the Korean pronunciation dictionary of KBS (1993) are monosyllabic.[30] This strongly suggests that a word size preference could motivate Korean speakers to change the word size of English monosyllables to a structure more consistent with Korean.

There are other cases where word size has been shown to be a factor in loanword adaptation and foreign language learning. Wang (1995) showed that Mandarin speaking learners of English were more likely to insert a vowel following a final obstruent in pronouncing monosyllabic than disyllabic nonce forms (72% vs. 18%). Similarly, Kao (2015) showed that in Indonesian loanwords, vowel insertion is observed only when a lexical root is monosyllabic while coalescence occurs when it is polysyllabic. In addition, Cardoso (2007) found that speakers of Brazilian Portuguese inserted a vowel more frequently in monosyllabic English words than in polysyllabic ones (accuracy of monosyllables vs. polysyllables for intermediate learners was 16% vs. 37%). Thus, the greater frequency of vowel epenthesis in monosyllabic forms than in polysyllabic ones does show up among second language learners of different language backgrounds. This word size effect is often referred to as a phonological markedness effect because a certain word size is preferred.

Another possible reason for the Korean speakers' tendency toward vowel insertion in English monosyllables could be the influence of Japanese loanwords in Korean, as Hirano (1994b) argues. Because of the Japanese prohibition on final obstruents, many English monosyllabic words are adapted into Japanese as disyllables with open final syllables (e.g., bed→beddo, cut→katto, ink→inku), and it is assumed that Korean borrowed these loanwords from Japanese (e.g., beddo→bedɨ, katto→kʌtɨ, inku→inkɨ). Kay (1995) and B. Kim (1998) list

[30] I checked this dictionary and there was a slight difference in percentages from those Hirano (1994a) indicated in his study. Monosyllabic stems (single morphemes) have a frequency of 0.83% out of all words, which include both single morphemic and multimorphemic words. The total number of words contained in the dictionary is 70,113 and the total number of monosyllabic stems is 580. I conducted a random sampling to see whether monosyllables are infrequent because Korean prefers disyllables or whether monosyllables are infrequent because bare stems are infrequent in the language. Three pages randomly chosen from the dictionary include 45 disyllabic bare stems and only one monosyllabic bare stem. Since the total page count is 677, there would be a fairly large number of disyllabic bare stems in the entire dictionary. This indicates that Korean definitely appears to prefer disyllabic words because monosyllables are infrequent although bare stems are frequent in Korean.

a large number of words that were borrowed into Korean through Japanese. Although there was indeed an effect of Japanese English-to-Korean adaptation, as Hirano (1994b) acknowledges, it is not easy to quantify exactly how many borrowings came into Korean through Japanese. All in all, the word size effect does not appear to follow from either the perceptual similarity or the misperception approach in which Korean listeners mistakenly interpret the acoustics of stop release as a vowel. However, if listeners are biased toward hearing structures that are legal in their native language, then the dispreference for monosyllabic words in Korean could bias listeners toward hearing an extra syllable in monosyllabic forms.

The misperception analysis of the word size effect is similar to the misperception analysis of the voicing effect: because a voiced stop can occur only prevocalically in Korean, Korean listeners hear an illusory vowel after the voiced stop. Although the voicing effect was not really confirmed in the syllable counting experiment, the misperception analysis that may apply to the voicing effect is also possible for the word size effect. Peperkamp and Dupoux (2003) claim that the phonological constraints of a language affect perception. That is, Japanese speakers heard an extra vowel in forms like *ebzo* because *ebzo* would not be legal in the language. Similarly, it is entirely possible that the Korean participants heard an extra syllable in monosyllabic forms because monosyllabic words are not preferred in Korean.

There could also be an acoustic/perceptual explanation for the word size effect. Nakatani and Schaffer (1978) report that monosyllables tend to be lengthened in English; monosyllabic words were longer by about 50ms than the equivalent syllables of disyllabic words (Nakatani & Schaffer 1978: 242). According to them, if the monosyllables in my stimuli were consistently longer than the corresponding final syllables in polysyllabic forms with final stress, we could argue that the length of the vowel preceding the final stop is a cue that Korean listeners use in determining whether the stop is word-final or prevocalic. However, measurement of the stimuli showed that even though monosyllabic items were slightly longer than equivalent syllables in polysyllabic items (484ms vs. 465ms), the length difference was not statistically significant ($p = 0.801$).

Vowel tenseness effect

We have seen that there was a significant effect of tense pre-final vowel in the similarity judgement task; Korean participants were more likely to judge an English final stop as similar to a Korean vowel-final item when the pre-final vowel was tense than when it was lax ($p < 0.001$). One might wonder about the relationship between forms with lax vowels vs. forms with tense monophthong vowels. Table 5.9 compares consonant-final vs. vowel-final responses for lax vs. tense monophthong items: the percent of vowel-final responses was very similar for forms with lax vs. tense monophthong vowels, with 30% of the forms with lax vowels judged to be similar to Korean vowel-final words, and 33% of the forms with tense monophthongs.

Table 5.9. Consonant-final vs. vowel-final responses: vowel tenseness

Tense vowels	C-final responses	V-final responses	C-final responses	V-final responses
Lax (e.g., [ɛ])	1269	531	71%	30%
Tense monophthong (e.g., [i:])	479	241	67%	33%

Post-hoc comparisons of vowel tenseness indicated that the difference between lax vs. tense monophthong items was not statistically significant ($p = 0.218$), suggesting that items with tense monophthong vowels were not significantly more likely to be judged as similar to Korean vowel-final than those with lax vowels. This finding might be due to the vowel duration of the stimuli. Measurements of the stimuli showed that the mean duration of lax vowels was longer than that of tense monophthong vowels (mean vowel duration: 145ms vs. 101ms), which may be a potential motivation for the only marginal difference in vowel-final response rate between the two types of vowels.

So far, we have seen results from three perception experiments. As discussed in Chapter 3, the results of the syllable counting experiment showed that two factors of release and vowel tenseness led to a greater likelihood of the perception of an illusory vowel. As discussed in Chapter 4, the results of the categorization experiment showed that four factors of release, voicing, vowel tenseness, and place increased the likelihood that an English final stop would be categorized as a stop followed by a vowel. In this chapter, the results of the similarity judgement experiment showed that four factors of release, vowel tenseness, place, and word size contributed to a greater likelihood of the judgements of English final stop as CV. Overall, the three perception tasks shared significant effects of primary factors: release and vowel tenseness. The categorization and the similarity judgment tasks shared a significant interaction of release and voicing, i.e., greater frequency of an epenthetic vowel after voiced than voiceless stops in unreleased stops as well as after voiceless than voiced stops in released stop. In the following chapter, I discuss why the common effects shown in the three experiments are important in the perception of Korean speakers.

Chapter 6
Conclusion

6.1 Overview

Korean speakers frequently insert a vowel after a word-final stop in English borrowed words into Korean, even though the stop-final form would be permissible in Korean since native Korean words may end in stops. A major goal of this dissertation was to determine whether this apparently unnecessary vowel insertion in loanwords derives from the misperception of English words or from a production grammar maintaining perceptual similarity between the English form and the Korean pronunciation.

I considered two possible approaches to explaining the apparently unmotivated vowel insertion: adaptation-in-production vs. adaptation-in-perception. The adaptation-in-production approach assumes that L2 forms are accurately perceived by the listener-borrowers in the same way as they are analyzed by English speakers, but that adapters transform the borrowed word into the perceptually closest native language form. For example, an English released final stop may be adapted as a stop plus vowel in Korean because although Korean listeners perceive the form as ending in a stop, they cannot preserve the stop release, since final stops are never released in Korean. Therefore, they adapt the English form as the Korean structure that is perceptually closest to the English released stop, which is a stop followed by a vowel. Alternatively, the adaptation-in-perception approach assumes that loanword adaptation occurs during the perception of foreign inputs. On this approach, a Korean speaker who produces a borrowed stop-final word as stop-vowel has actually interpreted the English form as ending in a vowel—for example, because they interpret English stop release as a vocalic segment.

I investigated seven linguistic factors which have been claimed to have an effect on vowel epenthesis in words borrowed into Korean: stop release, stop voicing, tenseness of the vowel preceding the final stop, position of word stress, place of articulation of the final stop, the [t-s] morphological alternation in Korean nouns, and word size. To investigate Korean speakers' production and perception of forms that differ in these factors, I carried out five studies: a corpus study of established loans, a production experiment in which Korean speakers heard and repeated English nonce forms, a syllable counting task, a categorization task, and a similarity judgment task. The results from the last three experiments show that three of these factors—release, voicing, and vowel tenseness—had a significant effect in the online perception of Korean listeners. I argued that the influence of these three factors is expected, considering the fact that these factors involve acoustic cues which can directly influence Koreans' perception of C vs. CV. It is also not surprising that the other factors, which are less directly related to perception, did not show consistent effects in the tasks designed to probe Korean speakers' perception of an illusory vowel.

6.2 Summary of findings

6.2.1 Production study

In Chapter 2, I reported on a corpus survey and a production experiment. The corpus study of established loanwords found 49% of English stop-final words adapted with a vowel inserted following the stop. In the production experiment, Korean speakers heard and repeated English nonce forms, which were carefully balanced to test the effects of the seven factors claimed to affect vowel insertion. The Korean speakers' productions were transcribed by native speakers of English. In contrast to the relatively high rate of vowel insertion found in the corpus, the transcriptions indicated vowel insertion in only 5% of the produced forms. These results might be taken to indicate that the Korean listeners did not perceive an illusory vowel in the English forms, and the results also seem to indicate that the listeners did not attempt to maintain perceptual similarity with released stops. The results are not conclusive, however, since acoustic analysis revealed that the burst noise intervals of the English final stops were significantly longer for Korean speakers than for English speakers. Thus, it is possible that the Korean speakers might have intended to produce a vowel, but that these vocalic elements were not long enough to be perceived as vowels by English speakers.

6.2.2 Perception experiments

In Chapters 3-5, I reported on three experiments designed to tap directly into Korean speakers' perception of English forms: (i) a syllable counting experiment, in which Korean speakers heard English nonce words ending in a stop, and indicated the number of syllables they heard in each word; (ii) a categorization experiment, in which Korean speakers heard English nonce words ending in a stop or a stop followed by a vowel, and categorized each word as consonant-final or vowel-final; and (iii) a similarity judgment experiment, in which Korean speakers heard a triplet consisting of an English stop-final form and two Korean forms, one ending in a stop and one ending in stop-vowel, and indicated which of the two Korean forms the English form sounded more similar to. In all three experiments, the stimuli were balanced to test the possible effects of each of the seven factors claimed to lead to vowel insertion.

Table 6.1 summarizes the effects found in the three perception experiments reported in Chapters 3 through 5. In all three tasks, the effects of final stop release and vowel tenseness preceding final stops were significant. Final stop voicing showed a less consistent result than expected: no voicing effect was found in the syllable counting task, whereas the other experiments did show a voicing effect, but this effect depended on release. For unreleased stops, vowel insertion was more likely after voiced than voiceless stops, while for released stops, the opposite was found, with vowel insertion more likely after voiceless than voiced stops.

Table 6.1. Significant effects in the perception experiments

Group	Factor	Syllable counting	Categorization	Similarity judgements
Primary factors	**Release**	√	√	√
	Vowel tenseness	√	√	√
	Voicing		√ [-rel]: +voi > -voi [+rel]: +voi < -voi	√ [-rel]: +voi > -voi [+rel]: +voi < -voi
Secondary factors	**Place**		√	√
	Stress			
Other factors	**Morphological alternations**			
	Word size			√

Overall, the results of the three behavioral experiments appear to provide a better fit with the approach that assumes a tendency to hear illusory vowels in certain contexts, so in the next section I will turn to why certain acoustic features favor perception of final C as CV.

6.3 Acoustic motivations for illusory vowel perception

6.3.1 Stop release

The fact that release was a significant effect in the three perception experiments suggests that Korean listeners were more likely to perceive an illusory vowel when they heard an English form ending in a released stop than when they heard a form ending in an unreleased stop—for example, interpreting both [kɛtʰ] and [kɛtʰɨ] as [kɛtʰɨ]. The strong effect of release raises the question of why the release factor should be so important in Korean loan phonology. Korean final stops are never released, while English postvocalic release has typically been assumed to be optional; that is, English stops may or may not be released word-finally (Gimson 1980; Crystal & House 1988; Byrd 1992). Gimson (1962: 151) mentions that the non-release of final stops is a feature of colloquial RP (Received Pronunciation), while release of final stops tends to be realized by rather careful speakers in more formal contexts.[31]

Many researchers have investigated stop release in English (Parker 1977; Jongman *et al.* 1985; Repp & Lin 1989; Jun & Beckman 1994; Song 2002; Kang 2003). Parker (1977) observes that an English released voiced stop often consists of a stop followed by a vocalic sound, while an English released voiceless stop consists of release burst plus aspiration noise. These phonetic events in English are very similar to those found in Korean CV sequences consisting of a voiceless consonant followed by a high vowel, where high vowels are devoiced following a voiceless consonant. Jun and Beckman (1994) examined a corpus containing CVCV words where the two consonants were voiceless and the first vowel was high, and found that the high vowels [i, u, ɨ] in Korean were devoiced 60-70% of the time after aspirated voiceless stops in both phrase-initial and phrase-medial position. As Kang (2003: 236) points out, we can suppose that vowels in phrase-final position would be even more devoiced than those in other positions, based on the fact that the amplitude of vowels in phrase-final position is weak in general. Song (2002) found similar devoicing in her study of Korean spontaneous speech based on recordings of ten speakers from live television programs. Her results confirm

[31] Here, Gimson (1962) describes the stylistic feature of word-final release on the basis of standard British English pronunciation. Yavas (2006) mentions that the final stops of American English also have a similar feature of release: word-final stops are normally unreleased in American English, but a speaker may pronounce them with a release burst. That is, in different speakers' pronunciations, we can find the released and unreleased allophones in an overlapping distribution (Yavas 2006: 46).

that high vowels [i, u, ɨ] are likely to be devoiced when they follow aspirated stops or affricates. Her data also suggest that vowels are significantly shorter when they follow aspirated stops [k^h, t^h, p^h] than when they follow lax [k, t, p] or tense [k’, t’, p’] stops.

Based on these phonetic properties of English stop release and Korean vowel devoicing, we can plausibly assume that an epenthetic vowel following an aspirated stop in Korean is not likely to be realized as a fully voiced segment. Therefore, the release portion of English stops may be phonetically close to a devoiced vowel in Korean, with the result that a short vocalic element is perceived as an illusory epenthetic vowel by Korean listeners.

6.3.2 Vowel tenseness

Recall that the accurate perception approach argues that the effect of vowel tenseness is dependent on stop release with respect to final vowel insertion (Kang 2003). That is, the reason why vowel tenseness favors vowel insertion in that approach is because tenseness makes release more likely in the English pronunciation. However, even though release was strictly balanced in the stimuli used in the perception experiments, the participants were still more likely to hear an illusory vowel when the English final stop was preceded by a tense vowel than when it was preceded by a lax vowel. This would suggest that a factor other than a tendency to be associated with release is required to account for the vowel tenseness effect.

The effect of tenseness is consistent with the fact that vowel duration is a cue to open vs. closed syllables in Korean. Han (1964) claimed that vowels in Korean are longer when they occur in open syllables than in closed syllables, and this was confirmed in studies of vowel duration by Koo (1998) and Chung and Huckvale (2001). Koo (1998), for example, found mean duration of 180.9ms for vowels in CV syllables vs. 87.9ms in CVC syllables. Thus, the pre-final vowel in [zi:p] has a duration more consistent with a syllable-final vowel, leading to the interpretation of this form as /zi.pɨ/.

6.3.3 Stop voicing

There are two possible motivations for a greater likelihood of vowel insertion after voiced than voiceless final stops in words borrowed from English. One motivation is phonotactic: in Korean, voiced stops occur only between sonorants, never in final position. The second possible motivation has to do with the acoustic cues to voicing in English, where vowels are typically longer before voiced than before voiceless consonants. The phonotactic approach predicts that Korean listeners will be more likely to hear an illusory vowel when an English final stop is voiced than when it is voiceless because Korean allows voicing to occur only between sonorants. However, this prediction holds only for unreleased final stops: in my results, perception of an illusory vowel was more likely following voiced than voiceless stops for unreleased stops, while released stops had the reverse direction with more voiceless stops misidentified as CV than voiced stops, as shown in Figure 6.1.[32]

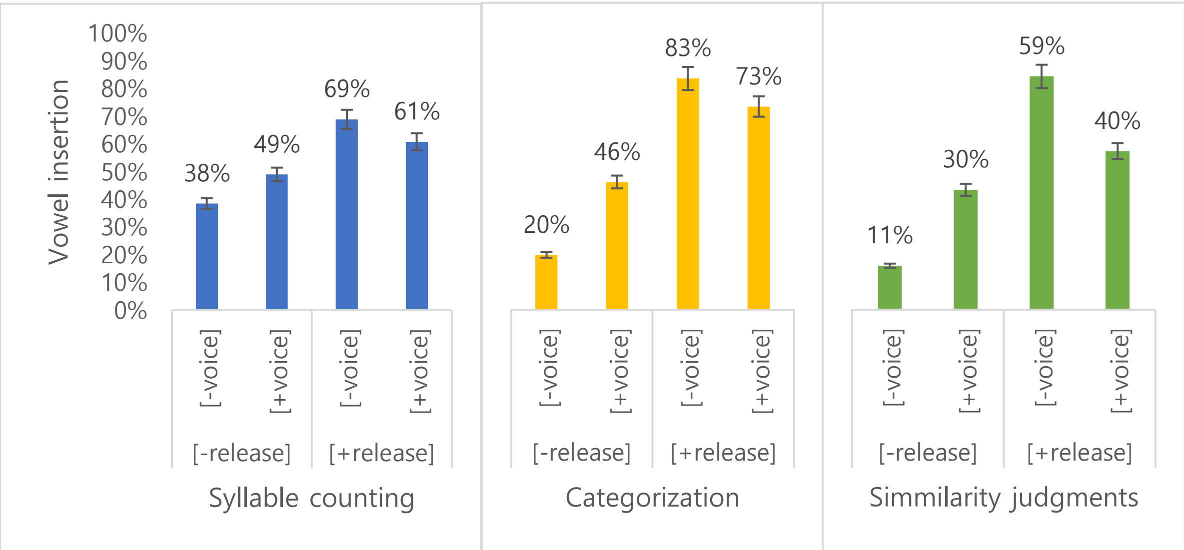

Figure 6.1. Vowel insertion rate by release and voicing of final stop in three tasks (Error bars indicate 95% confidence intervals)

32 Although the interaction of release and voicing was not statistically significant in the syllable counting task (syllable counting: $p = 0.054$, categorization & similarity judgments: $p < 0.001$), the Korean listeners' responses are similar across all three tasks when both release and voicing are taken into account.

The latter hypothesis, the cue-based view, provides an alternative explanation for the voicing effect. This approach predicts that Korean listeners will be more likely to perceive an illusory vowel when an English final stop is voiced than when it is voiceless since English vowels tend to be longer before voiced consonants. It has been reported that vowels in English have a tendency to be shorter before voiceless consonants—for example, the vowel in *bed* is phonetically longer than that in *bet* (House & Fairbanks 1953; Peterson & Lehiste 1960; Chen 1970; Naeser 1970; Raphael 1972; Klatt 1973; Crystal & House 1988; Kingston & Diehl 1994). The vowel duration cue of the English source form is tied to the phonetics of Korean vowels. As discussed before, Korean vowels tend to be longer in an open syllable than in a closed syllable in Korean (Han 1964; Koo 1998; Chung & Huckvale 2001). Hence, a primary cue to whether a final stop in English is voiced or voiceless is the duration of the preceding vowel, and the longer vowel before a voiced stop in English can make it easier for Korean listeners to hear CVC as CVCV when the final stop is voiced.

Experimental work confirms that Korean speakers are sensitive to English vowel length differences. Chang and Idsardi (2001) report that Korean participants correctly perceived durational differences of vowels in minimal pairs such as *bad* and *bat* and that they used the vowel-length cue employed by English native speakers when identifying English final stops. Chang (2006) carried out a set of experiments to investigate whether Korean learners can use the vowel duration cue to distinguish voicing in English word-final consonants. First, Korean and English listeners responded 'same' or 'different' to each auditory stimulus consisting of minimal pairs exhibiting a voicing contrast. The overall result showed that there was no difference between Korean and English speakers, although when the correct response rates were separated for stops vs. fricatives, Korean speakers were better than English speakers with stops and marginally worse than English speakers with fricatives. Second, in an identification task, Chang's participants listened to pairs of stimuli and were asked to identify which word they heard. His results showed that although Korean speakers had a lower rate of correct responses than English speakers, their correct response rate was far above chance level, which indicates that they did employ the vowel duration cue of English in this task. Third, he reports that in a production task, Korean speakers pronounced longer vowels before voiced consonants just as English speakers did, although there were duration differences between the groups. The results of the three different tests confirm that the vowel length cue is used by Korean speakers in both production and perception of English word-final voiced and voiceless consonants.

In summary, phonetic details of vowels in English and Korean contribute to the voicing effect: vowel duration is a major cue to voicing in English and it is also a cue to open vs. closed syllables in Korean. The measurements of the auditory stimuli used in the experiment for the current study indicated that the duration of mean vowels preceding final stops was consistently longer before voiced stops than before voiceless stops (132ms vs. 185ms). That is, when Korean listeners heard an English word ending in a voiced stop, the longer vowel preceding the voiced stop favored the perception of CVC as CVCV in Korean, e.g., [kɛd˺] is perceived as [kɛːdɨ], not as *[kɛ̆t˺]. This result is consistent with the results for unreleased stops, but not for released stops, where an illusory vowel was more likely following voiceless than voiced stops.

While vowel length alone cannot account for the opposite direction of the voicing effect for unreleased vs. released final stops, this pattern can be explained by looking at the acoustics of release. It has been reported that voiced and voiceless stops differ in the amount of pressure behind the stop closure, and the greater pressure in the production of voiceless stops leads to higher intensity bursts in voiceless stops than in voiced stops (Halle *et al*. 1957). Also, Crystal & House (1988) and Zue (1976) mention that the average duration of the release portion of voiced and voiceless stops differs greatly, with release in voiceless stops about twice as long as in voiced stops (Crystal & House 1988: 1558). The measurements of the auditory stimuli used in the experiment for the current study are consistent with this finding, showing that the mean duration of final stop release was longer for voiceless stops than for voiced stops (17ms vs. 21ms). Thus, it is possible that the longer duration of release in voiceless final stops made Korean listeners more likely to perceive an illusory vowel than the comparatively lower intensity and shorter release of voiced stops. Since the acoustic cues of the release are relevant only for released stops, this is consistent with the finding that an illusory vowel was more likely after a voiceless stop, but only for released stops.

To sum up, there were different effects for released vs. unreleased stops: the predicted voicing effect (a greater tendency to hear an illusory vowel after an English final voiced stop than a voiceless stop) was found only with unreleased stops. This could suggest that the release effect is more robust than the voicing effect, which was observed only when release was absent. This might be attributed to competition between release and voicing cues. That is, the release cue may be more perceptually salient than the voicing cue for Korean listeners, causing the release cue to veil the voicing cue. This raises the question of why the release cue might be more important for Korean speakers. The answer may lie in the system of Korean contrasts.

First, voicing is not used to signal phonemic contrast in Korean, where unaspirated stops become allophonically voiced between sonorants but voicing itself is never contrastive. However, release is one cue to the difference between final C and final CV since there is a three-way laryngeal contrast among lax, aspirated, and tense voiceless stops in nonfinal position, while word-final stops are never released. Thus, Korean has no contrast between a final released stop and a final stop followed by a vowel, while it does have a contrast between a final unreleased stop and a final stop followed by a vowel. For example, Korean does not seem to contrast [kɛt^{h}] and [kɛt^{h}ɨ] because released voiceless stops in English consist of release burst plus aspiration noise (Parker 1977), and Korean high vowels including [ɨ] are devoiced following a voiceless consonant (Jun & Beckman 1994; Song 2002).[33] Thus, the release portion of [kɛt^{h}] may be phonetically close to the resulting devoiced vowel in Korean, and therefore [kɛt^{h}] could be heard as [kɛt^{h}ɨ] by Korean ears. Unlike a final released stop, there is less possibility that [kɛt˺] could be perceived as [kɛt^{h}ɨ] (or rarely as [kɛdɨ]) because there is indeed a contrast between [kɛt˺] and [kɛt^{h}ɨ]. A final unreleased voiceless stop in [kɛt˺] is also different from a final unreleased voiced stop in [kɛd˺] because there is no contrast between [kɛd˺] and [kɛdɨ] in Korean. Korean listeners may perceive [kɛd˺] as [kɛdɨ] since the longer vowel preceding an English voiced stop can make the pre-final vowel longer in an open syllable than in a closed syllable in Korean.

There could be also an acoustic explanation for the interaction of release and voicing. Korean stops have a three-way laryngeal distinction in onset position, as mentioned before. Many researchers have reported that the acoustic cues to the laryngeal contrasts mainly occur at or near stop release in that all the phonetic information is given after the stop constriction is released (Lisker & Abramson 1964; Han & Weitzman 1970; Hardcastle 1973; Hirose *et al*. 1974; Han 1996; Cho *et al*. 2002; Choi 2002; Kim 2004; Kim & Duanmu 2004; Chang 2009). That is, because Korean speakers listen for VOT and F0 at release for cues to which of the

[33] Here, what Parker (1977) mentions as "release burst" may correspond to the acoustic events of transient plus frication that Kent & Read (2002) refer to, as discussed in Section 2.3.5.

three stops was produced, they pay special attention to what takes place at stop release. Therefore, this special role of stop release in Korean can make release cue more robust than voicing cue. This is consistent with a cue-based approach to second language perception where the perception of foreign forms is connected to L1-specific strategies for acoustic information rather than directly to L1 phonotactics (Chang 2018). According to this approach, the reason that L2 listeners have difficulties interpreting acoustic cues of L2 surface forms is because those cues do not have the same functions as in the native language (Ernestus et al. 2017). Chang (2018) reports that Korean listeners outperformed English speakers in an experiment in which Korean and English speakers were asked to distinguish CVCVC from CVCV in English stimuli where the final stop was unreleased. This is presumably because Korean listeners are more accustomed to paying attention to the cues that occur before a final stop than English listeners are. Chang argues that the Korean advantage in stop identification is due to the pattern of perceptual attention resulting from the phonology of the native language, showing that even Korean heritage speakers as well as Korean native speakers were better than English native speakers in a similar identification task (Chang 2016; 2018).

6.4 Concluding remarks

This dissertation expands on Kang's (2003) study of the apparently unmotivated insertion of vowels in stop-final words borrowed into Korean. Kang claims that Korean speakers accurately perceive the English forms but they insert a vowel in their production to maintain perceptual similarity between English stop release/voicing and the Korean epenthetic vowel. However, the results of my perception experiments suggest that in many cases, Korean L2 speakers interpret the foreign auditory forms according to the meaning of the acoustic cues in their native language. My experimental results were generally compatible with the adaptation-in-perception approach, but it is not the claim of this dissertation that the adaptation-in-production approach plays no role in unnecessary vowel insertion. Different experiments discussed in this work had differences in the results, providing different types of evidence: (i) evidence that can be explained by the adaptation-in-perception approach but not by the adaptation-in-production approach, e.g., release and vowel tenseness in syllable counting and categorization, voicing in categorization, and word size in similarity judgments; (ii) evidence that can be explained by the adaptation-in-production approach but not by the adaptation-in-perception approach, e.g., voicing in syllable counting, and word size in categorization; (iii) evidence that can be explained by both approaches, e.g., release and vowel tenseness in similarity judgments, place in syllable counting, and stress and morphological alternation in all three tasks; and (iv) evidence that cannot be explained by either approach, e.g., voicing in similarity judgments, place in categorization and similarity judgments, and word size in syllable counting. Other than the phonological factors that were considered in the present study, there are many other possible factors that may play a role in loan adaptation, e.g., orthography, explicit conventions of adaptation such as those of the Korean Academy, the adapters' knowledge of foreign language. That is, the phenomenon of unnecessary repair in Korean loanwords cannot be attributed only to misperception or only to maintaining perceptual similarity in production. Unnecessary vowel insertion is an intricate linguistic phenomenon that involves the complex interaction of perception and production.

References

Bates, Douglas, Martin Maechler, Ben Bolker, Steve Walker. 2015. Fitting Linear Mixed-Effects Models Using lme4. *Journal of Statistical Software*, 67 (1): 1-48.

Berent, Iris, Donca Steriade, Tracy Lennertz & Vered Vaknin. What we know about what we have never heard: evidence from perceptual illusions. *Cognition* 104: 591–630.

Best, Catherine. 1994. The emergence of native-language phonological influence in infants: A perceptual assimilation model. In J. Goodmand & H. Nusbaum (eds.), *The Development of Speech Perception*, 167-224. Cambridge: MIT Press.

Boersma, Paul & Bruce Hayes. 2001. Empirical tests of the Gradual Learning Algorithm. *Linguistic Inquiry* 32: 42-86.

Boersma, Paul & David Weenink. 2018. Praat: doing phonetics by computer [Computer program]. Version 6.0.37, retrieved 3 February 2018 from www.praat.org.

Boersma, Paul & Silke Hamann. 2009. Loanword adaptation as first-language phonological perception. In A. Calabrese & W. L. Wetzels (eds.), *Loanword phonology*, 11–58. Amsterdam/Philadelphia: John Benjamins Publishing Company.

Broselow, Ellen. 2009. Stress adaptation in loanword phonology: perception and learnability. In P. Boersma and S. Hamann (eds.), *Phonology in Perception*, 191-234. Berlin and New York: Mouton de Gruyter.

Broselow, Ellen. 2018. Laryngeal contrasts in second language phonology. In L. Hyman and F. Plank (eds.), *Phonological Typology*. Berlin/Boston: Walter de Gruyter, 312-340.

Broselow, Ellen & Yoonjung Kang. 2013. Second language phonology and speech. In. J. Herschensohn and M. Young-Scholten (eds.), *The Cambridge Handbook of Second Language Acquisition*, 529-554. Cambridge: Cambridge University Press.

Byrd, Dani. 1992. A note on English sentence-final stops. *UCLA Working Papers in Phonetics* 81: 37-38.

Byrd, Dani. 1993. 54000 American stops. *UCLA Working Papers in Phonetics* 83: 97-115.

Calabrese, Andrea. 2009. Perception, production and acoustic inputs in loanword phonology. In A. Calabrese & W. L. Wetzels (eds.), *Loanword phonology*, 59–114. Amsterdam/ Philadelphia: John Benjamins Publishing Company.

Cardoso, Walcir. 2005. The Variable Acquisition of English Word-final Stops by Brazilian Portuguese Speakers. In Laurent Dekydtspotter *et al.* (eds.), *Proceedings of the 7th Generative Approaches to Second Language Acquisition Conference (GASLA 2004)*, 38-49. Somerville, MA: Cascadilla Proceedings Project.

Cardoso, Walcir. 2007. The variable development of English word-final stops by Brazilian Portuguese speakers: a stochastic Optimality Theory account. *Language Variation and Change* 19: 219-248.

Chang, Charles B. 2009. The status of voicing and aspiration as cues to Korean laryngeal contrast. In M. Elliott, J. Kirby, O. Sawada, E. Staraki, & S. Yoon (eds.), *Proceedings from the 43rd Annual Meeting of the Chicago Linguistic Society: The Main Session*, 31-45. Chicago, IL: Chicago Linguistic Society.

Chang, Charles B. 2016. Bilingual perceptual benefits of experience with a heritage language. *Bilingualism: Language and Cognition* 19 (4): 791-809.

Chang, Charles B. 2018. Perceptual attention as the locus of transfer to nonnative speech perception. *Journal of Phonetics* 68: 85-102.

Chang, Woohyoek. 2006. Speech perception and production of English postvocalic voicing by Korean and English speakers. *Korean Journal of Speech Science* 13 (2): 107-120.

Chang, Woohyeok & William Idsardi. 2001. Speech perception and production of the English final voicing contrast by Korean speakers. *Harvard Studies in Korean Linguistics* 9: 117-129.

Chen, Matthew. 1970. Vowel length variation as a function of the voicing of the consonant environment. *Phonetica* 22: 129-159.

Cho, Taehong, Sun-Ah Jun, & Peter Ladefoged. 2002. Acoustic and aerodynamic correlates of Korean stops and fricatives. *Journal of Phonetics* 30 (2): 193-228.

Choi, Hansook. 2002. Acoustic cues for the Korean stop contrast–dialectal variation. *ZAS Papers in Linguistics* 28: 1-12.

Chung, Hyunsong & Mark Huckvale. 2001. Linguistic factors affecting timing in Korean with application to speech synthesis. *Proceedings of Eurospeech*, Volume 2: 815-818.

Coetzee, Andries. 2010. Syllables in speech processing: evidence from perceptual epenthesis. In Chuck Cairns and Eric Raimy (eds.), *Handbook of the Syllable*, 295-328. Leiden: E. J. Brill.

Crystal, Thomas & Arthur House. 1988. The duration of American-English stop consonants: an overview. *Journal of Phonetics* 16: 285-294.

Chung, Kook.1986. The role of [release] and CV-constraints in phonology: evidence from Korean. In The Linguistic Society of Korean (eds.) *Linguistics in the morning calm* 2, 317-336. Seoul: Hanshin.

Davidson, Lisa. 2011. Characteristics of stop releases in American English spontaneous speech. *Speech Communication* 53: 1042-1058.

Davidson, Lisa & Rolf Noyer. 1997. Loan phonology in Huave: Nativization and the ranking of faithfulness constraints. *Proceedings of the West Coast Conference on Formal Linguistics* 15: 65–79.

de Jong, Kenneth & Hanyong Park. 2012. Vowel epenthesis and segment identity in Korean learners of English. *Studies in Second Language Acquisition* 34: 127– 155.

de Jong, Kenneth & Mi-hui Cho. 2012. Loanword phonology and perceptual mapping: comparing two corpora of Korean contact with English. *Language* 88 (2): 341-368.

Dupoux, Emmanuel, Kazuhiko Kakehi, Yuki Hirose, Christophe Pallier & Jacques Mehler. 1999. Epenthetic vowels in Japanese: A perceptual illusion? *Journal of Experimental Psychology: Human Perception and Performance* 25: 1568-1578.

Dupoux, Emmanuel, Erika Parlato, Sonia Frota, Yuki Hirose & Sharon Peperkamp. 2011. Where do illusory vowels come from? *Journal of Memory and Language* 64: 199-210.

Ernestus, Mirjam, Huib Kouwenhoven, & Margot van Mulken. 2017. The direct and indirect effects of the phonotactic constraints in the listener's native language on the comprehension of reduced and unreduced word pronunciation variants in a foreign language. *Journal of Phonetics* 62: 50-64.

Fleischhacker, Heidi. 2005. *Similarity in phonology: Evidence from reduplication and loan adaptation*. Doctoral dissertation, University of California, Los Angeles.

Garofolo, John, Lori Lamel, William Fisher, Jonathan Fiscus, David Pallett, Nancy Dahlgren & Victor Zue. 1993. *TIMIT Acoustic-Phonetic Continuous Speech Corpus LDC93S1*. Web Download. Philadelphia: Linguistic Data Consortium.

Gimson, Alfred. 1962. *An introduction to the pronunciation of English*. London: Edward Arnold.

Gimson, Alfred. 1980. An introduction to the pronunciation of English. 3rd edition. London: Arnold.

Golston, Chris & Phong Yang. 2001. White Hmong loanword phonology. In Caroline Féry, Antony Dubach Green & Ruben van de Vijver (eds.), *Proceedings of HILP* 5: 40–57, Potsdam: University of Potsdam.

Gries, Stefan Th. 2013. *Statistics for linguistics with R: A practical introduction*. Berlin & Boston, MA: De Gruyter Mouton.

Halle, Morris, George W. Hughes, & Jean-Pierre A. Radley. 1957. Acoustic properties of stop consonants. *The Journal of the Acoustical Society of America* 29 (1): 107-116.

Han, Jeong-Im. 1996. *The phonetics and phonology of "tense" and "plain" consonants in Korean*. Doctoral dissertation, Cornell University.

Han, Mieko S. 1964. *Studies in the Phonology of Asian Language II: Duration of Korean vowels*. Los Angeles, CA: University of California.

Han, Mieko S. & Raymond S. Weitzman. 1970. Acoustic features of Korean /P, T, K/, /p, t, k/, and /p^h, t^h, k^h/. *Phonetica* 22: 112-128.

Hardcastle, William J. 1973. Some observations on the tense-lax distinction in initial stops in Korean. *Journal of Phonetics* 1: 263-272.

Hirano, Hideyuki. 1994a. Syllabification and Foot Structure in Korean: Evidence from loanwords. *The Annual Report of the Faculty of Art and Letters* 44. Tohoku University.

Hirano, Hideyuki. 1994b. A constraint-based approach to Korean loanwords. *Language Research* 30: 707-739.

Hirose, Hajaime, Charles Y. Lee, & Tatsujiro Ushijima. 1974. Laryngeal control in Korean stop production. *Journal of Phonetics* 2: 145-152.

House, Arthur & Grant Fairbanks. 1953. The influence of consonant environment upon the secondary acoustical characteristics of vowels. *The Journal of the Acoustical Society of America* 25: 105-113.

Huh, Woong. 1965. *국어음운학 [Korean phonology]*. Seoul: Cengumsa.

Itô, Junko & Armin Mester. 2001. Covert generalizations in Optimality Theory: The role of stratal faithfulness constraints. *Studies in Phonetics, Phonology, and Morphology* 7: 273–299.

Iverson, Gregory & Ahrong Lee. 2006. Perception of contrast in Korean loanword adaptation. *Korean Linguistics* 13: 49–87.

Jacobs, Haike & Carlos Gussenhoven. 2000. Loan phonology: Perception, salience, the lexicon and OT. In Joost Dekkers, Frank van der Leeuw & Jeroen van de Weijer (eds.), *Optimality Theory: Phonology, syntax, and acquisition*, 193–210. Oxford: Oxford University Press.

Jongman, Allard., Blumstein, Sheila Ellen & Lahiri, Aditi. 1985. Acoustic properties for dental and alveolar stop consonants: A cross-language study. *Journal of Phonetics* 13: 235-251.

Johnson, Keith. 2008. *Quantitative Methods in Linguistics*. Malden, MA: Blackwell.

Jun, Eun. 2002. 영어 차용어 음절 말 폐쇄음의 파열 여부와 모음 삽입에 관한 실험적 연구 [An experimental study of the effect of release of English syllable final stops on vowel epenthesis in English loanwords]. *Studies in Phonetics, Phonology and Morphology* 8: 117-134.

Jun, Sun-Ah. 1993. *The phonetics and phonology of Korean prosody*. Doctoral dissertation, The Ohio State University.

Jun, Sun-Ah & Mary Beckman. 1994. Distribution of devoiced high vowels in Korean. *Proceedings of the International Conference on Spoken Language Processing*, Volume 2: 479-482.

Kabak, Baris & William J. Idsardi. 2007. Perceptual distortions in the adaptation of English consonant clusters: Syllable structure or consonantal contact constraints? *Language and Speech* 50: 23–52.

Kang, Hyunsook. 1996. English loanwords in Korean. *Studies in Phonetics, Phonology and Morphology* 2: 21-47.

Kang, Ongmi. 1996. 한국어 차용 음운론에 대한 최적성이론 분석 [An optimality-theoretic analysis of Korean loanword phonology]. *Korean Linguistics* 28: 113-158.

Kang, Yoonjung. 2003. Perceptual similarity in loanword adaptation: English postvocalic word-final stops in Korean. *Phonology* 20: 219-273.

Kang, Yoonjung. 2011. Loanword phonology. In van Oostendorp, Marc, Colin Ewen, Elizabeth Hume, and Keren Rice (eds.), *The Blackwell Companion to Phonology: Phonological interfaces*, Volume 4: 2258-2282. Malden, MA: Wiley-Blackwell.

Kang, Yoonjung, Michael Kenstowicz & Chiyuki Ito. 2008. Hybrid loans: A study of English loanwords transmitted to Korean via Japanese. *Journal of East Asian Linguistics* 17: 299–316.

Kao, Sophia. 2015. Word minimality in Indonesian loanwords. Paper presented at CUNY Conference on Multiplingual Phonology. CUNY NY. January 16th.

Kawahara, Shigeto. 2006. A faithfulness ranking projected from a perceptibility scale: The case of [±voice] in Japanese. *Language* 82: 536–574.

Kay, Gillian. 1995. English loanwords in Japanese. *World Englishses* 14 (1): 67-76.

KBS (Korean Broadcasting System). 1993. *표준 한국어 발음 대사전 [The dictionary of Standard Korean pronunciation]*. Seoul: Eomunkak.

Kenstowicz, Michael & Hyang-Sook Sohn. 2001. Accentual adaptation in North Kyungsang Korean. In Michael Kenstowicz (eds.), *Ken Hale: A life in language*, 239-270. Cambridge, MA: MIT Press.

Kenstowicz, Michael 2003. The role of perception in loanword phonology: A review of *Les emprunts linguistiques d'origine européenne en Fon*. *Studies in African Linguistics* 32: 95–112.

Kenstowicz, Michael. 2005. The phonetics and phonology of loanword adaptation. In S.-J. Rhee (ed.), *Proceedings of ECKL 1: Proceedings of 1st European Conference on Korean Linguistics*, 17–32. Seoul: Hankook Publishing Co.

Kenstowicz, Michael 2007. Salience and similarity in loanword adaptation: A case study from Fijian. *Language Sciences* 29: 316–340.

Kenstowicz, Michael & Atiwong Suchato. 2006. Issues in loanword adaptation: A case study from Thai. *Lingua* 116: 921–949.

Kent, Ray & Charles Read. 2002. *The acoustic analysis of speech*. San Diego: Singular Press.

Kim, Bong-Mo. 1998. 우리말에 들어온 외래어 분석 [An analysis of loanwords through Japanese]. *Hanguk Minjok Munhwa* 11: 105-154.

Kim, Chin-Wu. 1971. Two phonological notes: A-sharp and B-flat. In Michael Brame (eds.), *Contributions to generative phonology*. Austin: University of Texas Press, 155-170.

Kim, Dae-Won. 2002. The vowel length as a function of the articulatory force of the following consonants in Korean. *Korean Journal of Speech Science* 9 (3): 143-153.

Kim, Kyumin & Alexei Kochetov. 2010. Phonology and phonetics of epenthetic vowels in loanwords: Experimental evidence from Korean. *Lingua* 121: 511-532.

Kim, Midam. 2004. Correlation between VOT and F0 in the perception of Korean stops and affricates. In *INTERSPEECH* 2004: 49-52.

Kim, Mi-Ryoung & San Duanmu. 2004. Tense and Lax stops in Korean. *Journal of East Asian Linguistics* 13: 59-104.

Kingston, John & Randy Diehl. 1994. Phonetic Knowledge. *Language* 70 (3): 419-454.

Klatt Dennis. 1973. Letter: Interaction between two factors that influence vowel duration. *The Journal of the Acoustical Society of America* 54 (4): 1102-1104.

Koo, Hee-San. 1998. 모음 길이에 미치는 자음 환경의 영향 [The influence of consonant environment upon the vowel duration]. *Korean Journal of Speech Science* 4 (1): 7-17.

Kwon, Harim. 2017. Language experience, speech perception and loanword adaptation: variable adaptation of English word-final plosives into Korean. *Journal of Phonetics* 60: 1-19.

LaCharité, Darlene & Carole Paradis. 2005. Category preservation and proximity versus phonetic approximation in loanword adaptation. *Linguistic Inquiry* 36: 223–258.

Ladefoged, Peter. 2006. *A course in Phonetics*. Oxford, UK: Blackwell.

Lim, B. J. 2003. *Perception, production, and orthography in syllabification in Korean and English*. Doctoral dissertation, Indiana University, Bloomington.

Lisker, Leigh. 1999. Perceiving final voiceless stops without release: effects of preceding monophthongs versus nonmonophthongs. *Phonetica* 56: 44-55.

Lisker, Leigh & Arthur Abramson. 1964. A cross-language study of voicing in initial stops: acoustical measurements. *Word* 20 (3): 384-422.

Miao, Ruiqin. 2006. *Loanword adaptation in Mandarin Chinese: Perceptual, phonological and sociolinguistic factors.* Doctoral dissertation, Stony Brook University.

Naeser, Margaret Ann. 1970. Influence of initial and final consonant on vowel duration in CVC syllables. *Technical Report No. 130*. Wisconsin Research and Development Center for Cognitive Learning, The University of Wisconsin, Madison.

Nakatani, Lloyd & Judith Schaffer. 1978. Hearing ‘words’ without words: prosodic cues for word perception. *The Journal of the Acoustical Society of America* 63: 234-245.

Padegett, Jaye. 2010. Systemic contrast and Catalan rhotics. *The Linguistic Review* 26 (4): 431-463.

Parker, Frank. 1977. Perceptual cues and phonological change. *Journal of Phonetics* 5: 97-105.

Paradis, Carole & Darlene Lacharité. 1997. Preservation and minimality in loanword adaptation. *Journal of Linguistics* 33: 379–430.

Paradis, Carole & Darlene Lacharité. 2008. Apparent phonetic approximation: English loanwords in old Quebec French. *Journal of Linguistics* 44: 87–128.

Paradis, Carole & Antoine Tremblay. 2009. Nondistinctive features in loanword adaptation: The unimportance of English aspiration in Mandarin Chinese phoneme categorization. In A. Calabrese & W. L. Wetzels (eds.), *Loanword phonology*, 211–224. Amsterdam/ Philadelphia: John Benjamins Publishing Company.

Peperkamp, Sharon. 2005. A psycholinguistic theory of loanword adaptation. In M. Ettlinger, N. Fleischer and M. Park-Doob (eds.), *Proceedings of the 30th Annual Meeting of the Berkeley Linguistics Society* 30: 341-352. Berkeley: Berkeley Linguistic Society.

Peperkamp, Sharon & Emmanuel Dupoux. 2003. Reinterpreting loanword adaptations: The role of perception. In M. J. Solé, D. Recasens & J. Romero (eds.), *Proceedings of the 15th International Congress of Phonetic Sciences*, 367-370. Barcelona: Causal Productions.

Peperkamp, Sharon, Inga Vendelin & Kimihiro Nakamura. 2008. On the perceptual origin of loanword adaptations: Experimental evidence from Japanese. *Phonology* 25: 129-164.

Peterson, Gordon & Ilse Lehiste. 1960. Duration of syllable nuclei in English. *The Journal of the Acoustical Society of America* 32 (6): 693–703.

R Core Team. 2016. *R: A language and environment for statistical computing*. R Foundation for Statistical Computing, Vienna, Austria.

Raphael, Lawrence. 1972. Preceding vowel duration as a cue to the perception of the voicing characteristics of word-final consonants in American English. *The Journal of the Acoustical Society of American* 51: 1296-1303.

Repp, Bruno & Hwei-Bing Lin. 1989. Acoustic properties and perception of stop consonant release transients. *The Journal of the Acoustical Society of America* 85: 379-396.

Rhee, Seok-Chae & Yoo-Kyung Choi. 2001. 영어 차용어의 모음 삽입에 대한 통계관찰과 그 의의 [A statistical observation of vowel insertion in English loanwords in Korean and its significance]. *Studies in Phonetics, Phonology and Morphology* 7: 153-176.

Shinohara, Shigeko. 2000. Default accentuation and foot structure in Japanese: Evidence from Japanese adaptations of French words. *Journal of East Asian Linguistics* 9: 55–96.

Shinohara, Shigeko. 2006. Perceptual effects in final cluster reduction patterns. *Lingua* 116: 1046–1078.

Silverman, Daniel. 1992. Multiple scansions in loanword phonology: evidence from Cantonese. *Phonology* 9: 289-328.

Smith, Jennifer. 2006. Loan phonology is not all perception: Evidence from Japanese loan doublets. In Timothy J. Vance & Kimberly A. Jones (eds.), *Japanese/Korean Linguistics* 14: 63-74. Palo Alto: CLSI.

Sohn, Ho-Min. 1999. *The Korean Language*. Cambridge University Press.

Song, Yoon-Kyoung. 2002. *한국어 대화체의 음성적 특성에 관한 연구: 음절의 지속 시간과 모음의 무성화를 중심으로* [*A study on phonetic characteristics of spontaneous speech: syllable duration and vowel devoicing*]. Doctoral dissertation, Seoul National University.

Steriade, Donca. 2001. Directional asymmetries in place assimilation: A perceptual account. In Elizabeth Hume & Keith Johnson (eds.), *The role of speech perception in phonology*, 219-250. San Diego: Academic Press.

Steriade, Donca. 2008. The phonology of perceptibility effects: The P-map and its consequences for constraint organization. In Kristin Hanson & Sharon Inkelas (eds.), *The nature of the word: Studies in honor of Paul Kiparsky*, 151-180. Cambridge, MA: MIT Press.

The National Academy of the Korean Language. 2001. *외래어 발음 실태 조사 [Survey of pronunciation of loanwords]*. Seoul: 국립국어연구원 [The National Academy of the Korean Language].

The National Academy of the Korean Language. 2002. *외래어 표기 용례집 [The guidelines for loanword orthography]*. Seoul: 국립국어연구원 [The National Academy of the Korean Language].

The National Academy of the Korean Language. 2007a. *외래어 사용 [The usage of loanwords]*. Seoul: 국립국어연구원 [The National Academy of the Korean Language].

The National Academy of the Korean Language. 2007b. *외래어 인지도·이해도·사용도 및 태도조사 [Recognition, understanding, usage and attitude to loanwords]*. Seoul: 국립국어연구원 [The National Academy of the Korean Language].

The National Academy of the Korean Language. 2010. *외래어 표기 규범 영향 평가 [The evaluation for the influence of loanword orthography]*. Seoul: 국립국어연구원 [The National Academy of the Korean Language].

Tsukada, Kimiko, David Birdsong, Molly Mack, Hyekyung Sung, Ellen Bialystok & James Flege. 2004. Release bursts in English word-final voiceless stops produced by native English and Korean adults and children. *Phonetica* 61: 67-83.

Vendelin, Inga & Sharon Peperkamp. 2004. Evidence for phonetic adaptation of loanwords: an experimental study. *Actes des IVèmes Journées d'Etudes Linguistiques de l'Université de Nantes, Nantes,* 129-131.

Wang, Chilin. 1995. *The acquisition of English word-final obstruents by Chinese speakers*. Doctoral dissertation, Stony Brook University.

Yavas, Mehmet. 2006. *Applied English Phonology*. Malden, MA & Oxford: Blackwell.

Yip, Moira. 2002. Necessary but not sufficient: Perceptual influences in loanword phonology. *Journal of the Phonetic Society of Japan* 6: 4–21.

Yip, Moira. 2006. The symbiosis between perception and grammar in loanword phonology. *Lingua* 116: 950–975.

Yun, Ilsung. 2009. Vowel duration and the feature of the following consonant. *Korean Journal of Speech Science* 1 (1): 41-46.

Zue, Victor Waito. 1976. *Acoustic characteristics of stop consonants: A controlled study*. Doctoral dissertation, Massachusetts Institute of Technology.

Appendix 1. Numeric data

Class	
Class 1	Vowel insertion
Class 2	No vowel insertion
Class 3	Optional vowel insertion

Linguistic factors	**Attributes**	**Notes**
Tenseness of pre-final vowel	Lax vowel (Vowel_L) Tense vowel (Vowel_T)	Vowel_L(1)=lax vowel Vowel_L(0)=tense vowel Vowel_T(1)=tense vowel Vowel_T(0)=lax vowel
Voicing of final stop	Voiceless stop (Stop_VL) Voiced stop (Stop_VD)	Stop_VL(1)=voiceless stop Stop_VL(0)=voiced stop Stop_VD(1)=voiced stop Stop_VD(0)=voiceless stop
Place of articulation of final stop	Dorsal stop (PoA_DOR) Coronal stop (PoA_COR) Labial stop (PoA_LAB)	PoA_DOR(1)=dorsal stop PoA_DOR(0)=nondorsal stop PoA_COR(1)=coronal stop PoA_COR(0)=noncoronal stop PoA_LAB(1)=labial stop PoA_LAB(0)=nonlabial stop
Syllabicity of word	Polysyllabic word (Syllables_P) Monosyllabic word (Syllables_M)	Syllables_P(1)=polysyllabic word Syllables_P(0)=monosyllabic word Syllables_M(1)=monosyllabic word Syllables_M(0)=polysyllabic word
Stress of final syllable	Nonstressed syllable (Stress_N) Stressed syllable (Stress)	Stress_N(1)=nonstressed syllable Stress_N(0)=stressed syllable Stress(1)=stressed syllable Stress(0)=nonstressed syllable

Class 1: Vowel insertion

No.	English word	Korean form	Class	V	C	Vowel_L	Vowel_T	Stop_VL	Stop_VD	PoA_DOR	PoA_COR	PoA_LAB	Syllables_P	Syllables_M	Stress_N	Stress
1	accent	aksɛntʰɨ	1	1	0	1	0	1	0	0	1	0	1	0	1	0
2	acetaldehyde	asɛtʰɨaltɛhitɨ	1	1	0	1	0	0	1	0	1	0	1	0	1	0
3	aldehyde	altɛhitɨ	1	1	0	1	0	0	1	0	1	0	1	0	1	0
4	analogue	analloki	1	1	0	1	0	0	1	1	0	0	1	0	1	0
5	antique	antʰikʰɨ	1	1	0	0	1	1	0	1	0	0	1	0	0	1
6	apartment	apʰatʰɨ, apʰatʰɨmʌntʰɨ	1	1	0	1	0	1	0	0	1	0	1	0	1	0
7	arcade	akeitɨ	1	1	0	0	1	0	1	0	1	0	1	0	0	1
8	Ark	akʰɨ	1	1	0	0	1	1	0	1	0	0	0	1	0	1
9	art	atʰɨ	1	1	0	0	1	1	0	0	1	0	0	1	0	1
10	artist	atʰisɨtʰɨ	1	1	0	1	0	1	0	0	1	0	1	0	1	0
11	attitude	ɛtʰitʰjutɨ	1	1	0	0	1	0	1	0	1	0	1	0	1	0
12	Asiad	asiatɨ	1	1	0	1	0	0	1	0	1	0	1	0	0	1
13	backlight	pæklaitʰɨ	1	1	0	0	1	1	0	0	1	0	1	0	1	0
14	bad	pætɨ	1	1	0	1	0	0	1	0	1	0	0	1	0	1
15	ballad	pallatɨ	1	1	0	1	0	0	1	0	1	0	1	0	1	0
16	bank	pæŋkʰɨ	1	1	0	1	0	1	0	1	0	0	0	1	0	1
17	baroque	palokʰɨ	1	1	0	0	1	1	0	1	0	0	1	0	0	1
18	barricade	palikʰɛitɨ	1	1	0	0	1	0	1	0	1	0	1	0	0	1
19	bat	pætʰɨ	1	1	0	1	0	1	0	0	1	0	0	1	0	1
20	baulk	pokʰɨ	1	1	0	0	1	1	0	1	0	0	0	1	0	1
21	bed	pɛtɨ	1	1	0	1	0	0	1	0	1	0	0	1	0	1
22	Belfast	pɛlpʰasɨtʰɨ	1	1	0	1	0	1	0	0	1	0	1	0	1	0
23	bike	paikʰɨ	1	1	0	0	1	1	0	1	0	0	0	1	0	1
24	bit	pitʰɨ	1	1	0	1	0	1	0	0	1	0	0	1	0	1
25	bite	paitʰɨ	1	1	0	0	1	1	0	0	1	0	0	1	0	1
26	Black Hawk	pɨllækhokʰɨ	1	1	0	0	1	1	0	1	0	0	1	0	0	1
27	blog	pɨlloki	1	1	0	0	1	0	1	1	0	0	0	1	0	1
28	boat	potʰɨ	1	1	0	0	1	1	0	0	1	0	0	1	0	1
29	bodyguard	potikatɨ	1	1	0	0	1	0	1	0	1	0	1	0	1	0
30	bond	pontɨ	1	1	0	0	1	0	1	0	1	0	0	1	0	1
31	boot	putʰɨ	1	1	0	0	1	1	0	0	1	0	0	1	0	1
32	bot	potʰɨ	1	1	0	0	1	1	0	0	1	0	0	1	0	1
33	brake	pɨlɛikʰɨ	1	1	0	0	1	1	0	1	0	0	0	1	0	1
34	brand	pɨlæntɨ	1	1	0	1	0	0	1	0	1	0	0	1	0	1
35	bug	pʌki	1	1	0	1	0	0	1	1	0	0	0	1	0	1
36	byte	paitʰɨ	1	1	0	0	1	1	0	0	1	0	0	1	0	1
37	CAD	kʰætɨ	1	1	0	1	0	0	1	0	1	0	0	1	0	1
38	cakewalk	kʰɛikʰɨwʌkʰɨ	1	1	0	0	1	1	0	1	0	0	1	0	1	0
39	cape	kʰɛipʰɨ	1	1	0	0	1	1	0	0	0	1	0	1	0	1
40	card	kʰatɨ	1	1	0	0	1	0	1	0	1	0	0	1	0	1
41	celluloid	sɛllulloitɨ	1	1	0	0	1	0	1	0	1	0	1	0	1	0
42	chalk	tʃʰokʰɨ	1	1	0	0	1	1	0	1	0	0	0	1	0	1
43	chart	tʃʰatʰɨ	1	1	0	0	1	1	0	0	1	0	0	1	0	1
44	classmate	kʰɨllæsɨmɛitʰɨ	1	1	0	0	1	1	0	0	1	0	1	0	1	0
45	cloud	kʰɨllautɨ	1	1	0	0	1	0	1	0	1	0	0	1	0	1
46	coat	kʰotʰɨ	1	1	0	0	1	1	0	0	1	0	0	1	0	1
47	compact	kʰompʰæktʰɨ	1	1	0	1	0	1	0	0	1	0	1	0	1	0
48	concert	kʰonsʌtʰɨ	1	1	0	1	0	1	0	0	1	0	1	0	1	0
49	concrete	kʰonkʰɨlitʰɨ	1	1	0	0	1	1	0	0	1	0	1	0	1	0
50	coordinate	kʰotinɛitʰɨ	1	1	0	0	1	1	0	0	1	0	1	0	1	0
51	court	kʰotʰɨ	1	1	0	0	1	1	0	0	1	0	0	1	0	1
52	creosote	kʰɨleosotʰɨ	1	1	0	0	1	1	0	0	1	0	1	0	1	0
53	date	tɛitʰɨ	1	1	0	0	1	1	0	0	1	0	0	1	0	1
54	dead	tɛtɨ	1	1	0	1	0	0	1	0	1	0	0	1	0	1
55	debate	tipɛitʰɨ	1	1	0	0	1	1	0	0	1	0	1	0	0	1
56	debug	tipʌki	1	1	0	1	0	0	1	1	0	0	1	0	0	1
57	desk	tɛsɨkʰɨ	1	1	0	1	0	1	0	1	0	0	0	1	0	1
58	diamond	taiamontɨ	1	1	0	1	0	0	1	0	1	0	1	0	1	0
59	diet	taiʌtʰɨ	1	1	0	1	0	1	0	0	1	0	1	0	1	0
60	diode	taiotɨ	1	1	0	0	1	0	1	0	1	0	1	0	1	0
61	disk	tisɨkʰɨ	1	1	0	1	0	1	0	1	0	0	0	1	0	1
62	download	taunlotɨ	1	1	0	0	1	0	1	0	1	0	1	0	0	1
63	drape	tɨlɛipʰɨ	1	1	0	0	1	0	1	0	0	1	0	1	0	1
64	dynamite	tainamaitʰɨ	1	1	0	0	1	1	0	0	1	0	1	0	1	0
65	east	isɨtʰɨ	1	1	0	0	1	1	0	0	1	0	0	1	0	1
66	ebonite	ɛponaitʰɨ	1	1	0	0	1	1	0	0	1	0	1	0	0	1
67	elevate	ɛllipɛitʰɨ	1	1	0	0	1	1	0	0	1	0	1	0	1	0
68	end	ɛntɨ	1	1	0	1	0	0	1	0	1	0	0	1	0	1
69	entertainment	ɛntʰʌtʰɛinmʌntʰɨ	1	1	0	1	0	1	0	0	1	0	1	0	1	0
70	epilogue	ɛpʰilloki	1	1	0	1	0	0	1	1	0	0	1	0	1	0

71	episode	ɛpʰisotɨ	1	1	0	0	1	0	1	0	1	0	1	0	1	0
72	etude	ɛtʰwitɨ	1	1	0	0	1	0	1	0	1	0	1	0	1	0
73	event	ipɛntʰɨ	1	1	0	1	0	1	0	0	1	0	0	1	0	1
74	fog	pʰokɨ	1	1	0	1	0	0	1	1	0	0	0	1	0	1
75	food	pʰutɨ	1	1	0	0	1	0	1	0	1	0	0	1	0	1
76	formaldehyde	pʰolɨmaltɛhitɨ	1	1	0	1	0	0	1	0	1	0	1	0	1	0
77	fried	pʰɨlaitɨ	1	1	0	0	1	0	1	0	1	0	0	1	0	1
78	fruit	pʰulɨtʰɨ	1	1	0	0	1	1	0	0	1	0	0	1	0	1
79	gag	kækɨ	1	1	0	1	0	0	1	1	0	0	0	1	0	1
80	gate	kɛitʰɨ	1	1	0	0	1	1	0	0	1	0	0	1	0	1
81	geneat	kinitʰɨ	1	1	0	0	1	1	0	0	1	0	1	0	0	1
82	gigabit	kikapitʰɨ	1	1	0	1	0	1	0	0	1	0	1	0	0	1
83	glycoside	kɨllikʰosaitɨ	1	1	0	0	1	0	1	0	1	0	1	0	1	0
84	grade	kɨlɛitʰɨ	1	1	0	0	1	0	1	0	1	0	0	1	0	1
85	grape	kɨlɛipʰɨ	1	1	0	0	1	1	0	0	0	1	0	1	0	1
86	great	kɨlɛitʰɨ	1	1	0	0	1	1	0	0	1	0	0	1	0	1
87	guide	kaitɨ	1	1	0	0	1	1	0	0	1	0	0	1	0	1
88	guild	kiltɨ	1	1	0	1	0	0	1	0	1	0	0	1	0	1
89	guitarist	kitʰalisɨtʰɨ	1	1	0	1	0	1	0	0	1	0	1	0	1	0
90	gut	kʌtʰɨ	1	1	0	1	0	1	0	0	1	0	0	1	0	1
91	hand	hæntɨ	1	1	0	1	0	0	1	0	1	0	0	1	0	1
92	handmade	hæntɨmɛitɨ	1	1	0	0	1	0	1	0	1	0	1	0	0	1
93	hard	hatɨ	1	1	0	0	1	0	1	0	1	0	0	1	0	1
94	harddisk	hatɨtisɨkʰɨ	1	1	0	1	0	1	0	1	0	0	1	0	1	0
95	headlight	hɛtɨlaitʰɨ	1	1	0	0	1	1	0	0	1	0	1	0	1	0
96	highlight	haillaitʰɨ	1	1	0	0	1	1	0	0	1	0	1	0	1	0
97	hit	hitʰɨ	1	1	0	1	0	1	0	0	1	0	0	1	0	1
98	hood	hutɨ	1	1	0	1	0	0	1	0	1	0	0	1	0	1
99	hoop	hupʰɨ	1	1	0	0	1	1	0	0	0	1	0	1	0	1
100	host	hosɨtʰɨ	1	1	0	0	1	1	0	0	1	0	0	1	0	1
101	Hotdog	hastokɨ	1	1	0	0	1	0	1	1	0	0	1	0	1	0
102	Hula-Hoop	hullahupʰɨ	1	1	0	0	1	1	0	0	0	1	1	0	1	0
103	hybrid	haipɨlitɨ	1	1	0	1	0	0	1	0	1	0	1	0	1	0
104	illustrate	illʌsɨtʰɨlɛitʰɨ	1	1	0	0	1	1	0	0	1	0	1	0	1	0
105	incite	insaitʰɨ	1	1	0	0	1	1	0	0	1	0	1	0	0	1
106	ink	iŋkʰɨ	1	1	0	1	0	1	0	1	0	0	0	1	0	1
107	innocent	inosɛntʰɨ	1	1	0	1	0	1	0	0	1	0	1	0	1	0
108	inside	insaitɨ	1	1	0	0	1	0	1	0	1	0	1	0	0	1
109	institute	insɨtʰitʰjutʰɨ	1	1	0	0	1	1	0	0	1	0	1	0	1	0
110	jet	tʃɛtʰɨ	1	1	0	1	0	1	0	0	1	0	0	1	0	1
111	joke	tʃokʰɨ	1	1	0	0	1	1	0	1	0	0	0	1	0	1
112	keypad	kipʰætɨ	1	1	0	1	0	0	1	0	1	0	1	0	1	0
113	kid	kitɨ	1	1	0	1	0	0	1	0	1	0	0	1	0	1
114	kilt	kʰiltʰɨ	1	1	0	1	0	1	0	0	1	0	0	1	0	1
115	knit	nitʰɨ	1	1	0	1	0	1	0	0	1	0	0	1	0	1
116	lake	lɛikʰɨ	1	1	0	0	1	1	0	1	0	0	0	1	0	1
117	laminate	laminɛitʰɨ	1	1	0	1	0	1	0	0	1	0	1	0	1	0
118	land	læntɨ	1	1	0	1	0	0	1	0	1	0	0	1	0	1
119	lead	litɨ	1	1	0	0	1	0	1	0	1	0	0	1	0	1
120	league	likɨ	1	1	0	0	1	0	1	1	0	0	0	1	0	1
121	light	laitʰɨ	1	1	0	0	1	1	0	0	1	0	0	1	0	1
122	load	lotɨ	1	1	0	0	1	0	1	0	1	0	0	1	0	1
123	loop	lupʰɨ	1	1	0	0	1	1	0	0	0	1	0	1	0	1
124	lute	ljutʰɨ	1	1	0	0	1	1	0	0	1	0	0	1	0	1
125	magnesite	makɨnɛsaitʰɨ	1	1	0	0	1	1	0	0	1	0	1	0	0	1
126	mascot	masɨkʰotʰɨ	1	1	0	1	0	1	0	0	1	0	1	0	1	0
127	mat	mætʰɨ	1	1	0	1	0	1	0	0	1	0	0	1	0	1
128	mate	mɛitʰɨ	1	1	0	0	1	1	0	0	1	0	0	1	0	1
129	megabit	mɛkapitʰɨ	1	1	0	1	0	1	0	0	1	0	1	0	1	0
130	megabyte	mɛkapaitʰɨ	1	1	0	0	1	1	0	0	1	0	1	0	1	0
131	MIG	mikɨ	1	1	0	1	0	0	1	1	0	0	0	1	0	1
132	mike	maikʰɨ	1	1	0	0	1	1	0	1	0	0	0	1	0	1
133	minuet	minjuɛtʰɨ	1	1	0	1	0	1	0	0	1	0	1	0	0	1
134	mitt	mitʰɨ	1	1	0	1	0	1	0	0	1	0	0	1	0	1
135	mode	motɨ	1	1	0	0	1	0	1	0	1	0	0	1	0	1
136	mood	mutɨ	1	1	0	0	1	0	1	0	1	0	0	1	0	1
137	Mook	mukʰɨ	1	1	0	0	1	1	0	1	0	0	0	1	0	1
138	moot	motʰɨ	1	1	0	0	1	1	0	0	1	0	0	1	0	1
139	motorboat	motʰʌpotʰɨ	1	1	0	0	1	1	0	0	1	0	1	0	1	0
140	multi-cube	mʌltʰikʰjupɨ	1	1	0	0	1	0	1	0	0	1	1	0	1	0

141	network	nɛtʰɨwʌkʰɨ	1	1	0	0	1	1	0	1	0	0	1	0	1	0
142	night	naitʰɨ	1	1	0	0	1	1	0	0	1	0	0	1	0	1
143	node	notɨ	1	1	0	0	1	0	1	0	1	0	0	1	0	1
144	no-hit	nohitʰɨ	1	1	0	1	0	1	0	0	1	0	1	0	0	1
145	note	notʰɨ	1	1	0	0	1	1	0	0	1	0	0	1	0	1
146	nude	nutɨ	1	1	0	0	1	0	1	0	1	0	0	1	0	1
147	nut	nʌtʰɨ	1	1	0	1	0	1	0	0	1	0	0	1	0	1
148	oak	okʰɨ	1	1	0	0	1	1	0	1	0	0	0	1	0	1
149	offside	opʰɨsaitɨ	1	1	0	0	1	0	1	0	1	0	1	0	0	1
150	Olympiad	ollimpʰiatɨ	1	1	0	1	0	0	1	0	1	0	1	0	1	0
151	orchid	okʰitɨ	1	1	0	1	0	0	1	0	1	0	1	0	1	0
152	overhead	opʌhɛtɨ	1	1	0	1	0	0	1	0	1	0	1	0	0	1
153	PAD	pʰætɨ	1	1	0	1	0	0	1	0	1	0	0	1	0	1
154	paint	pʰɛintʰɨ	1	1	0	0	1	1	0	0	1	0	0	1	0	1
155	parade	pʰʌlɛitɨ	1	1	0	0	1	0	1	0	1	0	1	0	0	1
156	peak	pʰikʰɨ	1	1	0	0	1	1	0	1	0	0	0	1	0	1
157	peptide	pʰɛptʰaitɨ	1	1	0	0	1	0	1	0	1	0	1	0	1	0
158	period	pʰiliʌtɨ	1	1	0	1	0	0	1	0	1	0	1	0	1	0
159	pipe	pʰaipʰɨ	1	1	0	0	1	1	0	0	0	1	0	1	0	1
160	plaque	pʰɨllakɨ	1	1	0	1	0	1	0	1	0	0	0	1	0	1
161	plate	pʰɨllɛitʰɨ	1	1	0	0	1	1	0	0	1	0	0	1	0	1
162	plug	pʰɨllʌkɨ	1	1	0	1	0	0	1	1	0	0	0	1	0	1
163	Polaroid	pʰollaloitɨ	1	1	0	0	1	0	1	0	1	0	1	0	1	0
164	polyamide	pʰolliamitɨ	1	1	0	0	1	0	1	0	1	0	1	0	1	0
165	pound	paundtɨ	1	1	0	0	1	0	1	0	1	0	0	1	0	1
166	pride	pʰɨlaitɨ	1	1	0	0	1	0	1	0	1	0	0	1	0	1
167	print	pʰɨlintʰɨ	1	1	0	1	0	1	0	0	1	0	0	1	0	1
168	project	pʰɨlotʃɛktʰɨ	1	1	0	1	0	1	0	0	1	0	1	0	1	0
169	Prolog	pʰɨlollokɨ	1	1	0	1	0	0	1	1	0	0	1	0	1	0
170	prologue	pʰɨlollokɨ	1	1	0	1	0	0	1	1	0	0	1	0	1	0
171	punk	pʰʌŋkʰɨ	1	1	0	1	0	1	0	1	0	0	0	1	0	1
172	putt	pʰʌtʰɨ	1	1	0	1	0	1	0	0	1	0	0	1	0	1
173	rate	lɛitʰɨ	1	1	0	0	1	1	0	0	1	0	0	1	0	1
174	read	litɨ	1	1	0	0	1	0	1	0	1	0	0	1	0	1
175	recruit	likʰɨlutʰɨ	1	1	0	0	1	1	0	0	1	0	1	0	0	1
176	red	lɛtɨ	1	1	0	1	0	0	1	0	1	0	0	1	0	1
177	reed	litɨ	1	1	0	0	1	0	1	0	1	0	0	1	0	1
178	remote	limotʰɨ	1	1	0	0	1	1	0	0	1	0	1	0	0	1
179	report	lipʰotʰɨ	1	1	0	0	1	1	0	0	1	0	1	0	0	1
180	right	laitʰɨ	1	1	0	0	1	1	0	0	1	0	0	1	0	1
181	ringside	liŋsaitɨ	1	1	0	0	1	0	1	0	1	0	1	0	1	0
182	road	lotɨ	1	1	0	0	1	0	1	0	1	0	0	1	0	1
183	rogue	lokɨ	1	1	0	0	1	0	1	1	0	0	0	1	0	1
184	roommate	lummɛitʰɨ	1	1	0	0	1	1	0	0	1	0	1	0	1	0
185	root	lutʰɨ	1	1	0	0	1	1	0	0	1	0	0	1	0	1
186	rope	lopʰɨ	1	1	0	0	1	1	0	0	0	1	0	1	0	1
187	route	lutʰɨ	1	1	0	0	1	1	0	0	1	0	0	1	0	1
188	salad	sællʌtɨ	1	1	0	1	0	0	1	0	1	0	1	0	1	0
189	scope	sɨkʰopʰɨ	1	1	0	0	1	1	0	0	0	1	0	1	0	1
190	Scud	sɨkʰʌtɨ	1	1	0	1	0	0	1	0	1	0	0	1	0	1
191	seat	sitʰɨ	1	1	0	0	1	1	0	0	1	0	0	1	0	1
192	seed	sitɨ	1	1	0	0	1	0	1	0	1	0	0	1	0	1
193	serenade	sɛlɛnatɛ	1	1	0	0	1	0	1	0	1	0	1	0	0	1
194	shade	sjɛitɨ	1	1	0	0	1	0	1	0	1	0	0	1	0	1
195	shake	sjɛikʰɨ	1	1	0	0	1	1	0	1	0	0	0	1	0	1
196	sharp	sjapʰɨ	1	1	0	0	1	1	0	0	0	1	0	1	0	1
197	sheet	sitʰɨ	1	1	0	0	1	1	0	0	1	0	0	1	0	1
198	shock	sokʰɨ	1	1	0	1	0	1	0	1	0	0	0	1	0	1
199	side	saitɨ	1	1	0	0	1	0	1	0	1	0	0	1	0	1
200	Silk Load	silkʰɨlotɨ	1	1	0	0	1	0	1	0	1	0	1	0	1	0
201	site	saitʰɨ	1	1	0	0	1	1	0	0	1	0	0	1	0	1
202	skate	sɨkʰɛitʰɨ	1	1	0	0	1	1	0	0	1	0	0	1	0	1
203	skinhead	sɨkʰinhɛtɨ	1	1	0	1	0	0	1	0	1	0	1	0	1	0
204	skylight	sɨkʰailaitʰɨ	1	1	0	0	1	1	0	0	1	0	1	0	1	0
205	slate	sɨllɛitʰɨ	1	1	0	0	1	1	0	0	1	0	0	1	0	1
206	slide	sɨllaitɨ	1	1	0	0	1	0	1	0	1	0	0	1	0	1
207	slope	sɨllopʰɨ	1	1	0	0	1	1	0	0	0	1	0	1	0	1
208	smart	sɨmatʰɨ	1	1	0	0	1	1	0	0	1	0	0	1	0	1
209	smog	sɨmokɨ	1	1	0	0	1	0	1	1	0	0	0	1	0	1
210	solid	sollitɨ	1	1	0	1	0	0	1	0	1	0	1	0	1	0

211	sound	sauntɨ	1	1	0	0	1	0	1	0	1	0	0	1	0	1
212	Soviet	sopiɛtʰɨ	1	1	0	1	0	1	0	0	1	0	1	0	1	0
213	speed	sɨpʰitɨ	1	1	0	0	1	0	1	0	1	0	0	1	0	1
214	spike	sɨpʰaikʰɨ	1	1	0	0	1	1	0	1	0	0	0	1	0	1
215	spotlight	sɨpʰotʰɨlaitʰɨ	1	1	0	0	1	1	0	0	1	0	1	0	1	0
216	spreadsheet	sɨpʰɨlɛtɨsitʰɨ	1	1	0	0	1	1	0	0	1	0	1	0	1	0
217	stand	sɨtʰæntɨ	1	1	0	1	0	0	1	0	1	0	0	1	0	1
218	state	sɨtʰɛitʰɨ	1	1	0	0	1	1	0	0	1	0	0	1	0	1
219	steak	sɨtʰɛikʰɨ	1	1	0	0	1	1	0	1	0	0	0	1	0	1
220	steroid	sɨtʰɛloitɨ	1	1	0	0	1	0	1	0	1	0	1	0	1	0
221	straight	sɨtʰɨlɛitʰɨ	1	1	0	0	1	1	0	0	1	0	0	1	0	1
222	street	sɨtʰɨlitʰɨ	1	1	0	0	1	1	0	0	1	0	0	1	0	1
223	strike	sɨtʰɨlaikʰɨ	1	1	0	0	1	1	0	1	0	0	0	1	0	1
224	stripe	sɨtʰɨlaipʰɨ	1	1	0	0	1	1	0	0	0	1	0	1	0	1
225	stroke	sɨtʰɨlokʰɨ	1	1	0	0	1	1	0	1	0	0	0	1	0	1
226	suede	sɨwɛitɨ	1	1	0	0	1	0	1	0	1	0	0	1	0	1
227	suit	sutʰɨ, sjutʰɨ	1	1	0	0	1	1	0	0	1	0	0	1	0	1
228	superlight	sjupʰʌlaitʰɨ	1	1	0	0	1	1	0	0	1	0	1	0	1	0
229	support	s'ʌpʰotʰɨ	1	1	0	0	1	1	0	0	1	0	1	0	0	1
230	sweet	sɨwitʰɨ	1	1	0	0	1	1	0	0	1	0	0	1	0	1
231	syndicate	sintikʰɛitʰɨ	1	1	0	1	0	1	0	0	1	0	1	0	1	0
232	tabloid	tʰapɨlloitɨ	1	1	0	0	1	0	1	0	1	0	1	0	1	0
233	talk	tʰokʰɨ	1	1	0	0	1	1	0	1	0	0	0	1	0	1
234	teak	tʰikʰɨ	1	1	0	0	1	1	0	1	0	0	0	1	0	1
235	teammate	tʰimmɛitʰɨ	1	1	0	0	1	1	0	0	1	0	1	0	1	0
236	tent	tʰɛntʰɨ	1	1	0	1	0	1	0	0	1	0	0	1	0	1
237	test	tʰɛsɨtʰɨ	1	1	0	1	0	1	0	0	1	0	0	1	0	1
238	tiebreak	tʰaipɨlɛikʰɨ	1	1	0	0	1	1	0	1	0	0	1	0	1	0
239	tight	tʰaitʰɨ	1	1	0	0	1	1	0	0	1	0	0	1	0	1
240	tollgate	tʰolkɛitʰɨ	1	1	0	0	1	1	0	0	1	0	1	0	0	1
241	trade	tʰɨlɛitɨ	1	1	0	0	1	0	1	0	1	0	0	1	0	1
242	trend	tʰɨlɛntɨ	1	1	0	1	0	0	1	0	1	0	0	1	0	1
243	tube	tʰjupɨ	1	1	0	0	1	0	1	0	0	1	0	1	0	1
244	turnpike	tʰʌnpʰaikʰɨ	1	1	0	0	1	1	0	1	0	0	1	0	1	0
245	underground	ʌntʌkɨlauntɨ	1	1	0	0	1	0	1	0	1	0	1	0	1	0
246	unique	junikʰɨ	1	1	0	0	1	1	0	1	0	0	1	0	0	1
247	United	junaitʰitɨ	1	1	0	1	0	0	1	0	1	0	1	0	1	0
248	Universiade	junipʌsiatɨ	1	1	0	1	0	0	1	0	1	0	1	0	0	1
249	update	ʌptɛitʰɨ	1	1	0	0	1	1	0	0	1	0	1	0	0	1
250	upgrade	ʌpkɨlɛitɨ	1	1	0	0	1	0	1	0	1	0	1	0	0	1
251	upload	ʌplotɨ	1	1	0	0	1	0	1	0	1	0	1	0	1	0
252	upright	ʌplaitʰɨ	1	1	0	0	1	1	0	0	1	0	1	0	1	0
253	vote	potʰɨ	1	1	0	0	1	1	0	0	1	0	0	1	0	1
254	Watergate	wʌtʰʌkɛitʰɨ	1	1	0	0	1	1	0	0	1	0	1	0	0	1
255	watt	watʰɨ	1	1	0	0	1	1	0	0	1	0	0	1	0	1
256	website	wɛpsaitʰɨ	1	1	0	0	1	1	0	0	1	0	1	0	1	0
257	week	wikʰɨ	1	1	0	0	1	1	0	1	0	0	0	1	0	1
258	weight	wɛitʰɨ	1	1	0	0	1	1	0	0	1	0	0	1	0	1
259	west	wɛsɨtʰɨ	1	1	0	1	0	1	0	0	1	0	0	1	0	1
260	white	hwaitʰɨ	1	1	0	0	1	1	0	0	1	0	0	1	0	1
261	wide	waitɨ	1	1	0	0	1	0	1	0	1	0	0	1	0	1
262	wit	witʰɨ	1	1	0	1	0	1	0	0	1	0	0	1	0	1
263	wood	utɨ	1	1	0	1	0	0	1	0	1	0	0	1	0	1
264	yacht	jotʰɨ	1	1	0	0	1	1	0	0	1	0	0	1	0	1

Class 2: No vowel insertion

No.	English word	Korean form	Class	V	C	Vowel_L	Vowel_T	Stop_VL	Stop_VD	PoA_DOR	PoA_COR	PoA_LAB	Syllables_P	Syllables_M	Stress_N	Stress
1	academic	ak^{h}atɛmik	2	0	1	1	0	1	0	1	0	0	1	0	1	0
2	acoustic	ʌk^{h}usɨt^{h}ik	2	0	1	1	0	1	0	1	0	0	1	0	1	0
3	ad lib	ætɨlip	2	0	1	1	0	0	1	0	1	0	1	0	0	1
4	aerobic	ɛʌlopik	2	0	1	1	0	1	0	1	0	0	1	0	1	0
5	alphabet	alp^{h}apɛs	2	0	1	1	0	1	0	0	1	0	1	0	1	0
6	Arab	alap	2	0	1	1	0	0	1	0	0	1	1	0	1	0
7	assistantship	ʌsisɨt^{h}ʌnsip	2	0	1	1	0	1	0	0	0	1	1	0	1	0
8	attack	ʌt^{h}æk	2	0	1	1	0	1	0	1	0	0	1	0	0	1
9	automatic	ot^{h}omæt^{h}ik	2	0	1	1	0	1	0	1	0	0	1	0	1	0
10	back-up	pækʌp	2	0	1	1	0	1	0	0	0	1	1	0	1	0
11	bag	pæk	2	0	1	1	0	0	1	1	0	0	0	1	0	1
12	BASIC	pɛitʃik	2	0	1	1	0	1	0	1	0	0	1	0	1	0
13	basket	pasɨk^{h}ɛs	2	0	1	1	0	1	0	0	1	0	1	0	1	0
14	bebop	pipap	2	0	1	1	0	1	0	0	0	1	1	0	1	0
15	big	pik	2	0	1	1	0	0	1	1	0	0	0	1	0	1
16	bioceramic	paiosɛlamik	2	0	1	1	0	1	0	1	0	0	1	0	1	0
17	bioplastic	paiop^{h}ɨllasɨt^{h}ik	2	0	1	1	0	1	0	1	0	0	1	0	1	0
18	black	pɨllæk	2	0	1	1	0	1	0	1	0	0	0	1	0	1
19	bloc	pɨllok	2	0	1	1	0	1	0	1	0	0	0	1	0	1
20	block	pɨllʌk	2	0	1	1	0	1	0	1	0	0	0	1	0	1
21	book	puk	2	0	1	1	0	1	0	1	0	0	0	1	0	1
22	cabinet	k^{h}æpinɛs	2	0	1	1	0	1	0	0	1	0	1	0	1	0
23	Cadillac	k^{h}ætillak	2	0	1	1	0	1	0	1	0	0	1	0	1	0
24	cap	k^{h}æp	2	0	1	1	0	1	0	0	0	1	0	1	0	1
25	carat	k^{h}ælʌs	2	0	1	1	0	1	0	0	1	0	1	0	1	0
26	Catholic	k^{h}at^{h}ollik, kat^{h}ollik	2	0	1	1	0	1	0	1	0	0	1	0	1	0
27	ceramic	sɛlamik	2	0	1	1	0	1	0	1	0	0	1	0	1	0
28	championship	tʃ^{h}æmpiʌnsip	2	0	1	1	0	1	0	0	0	1	1	0	1	0
29	change-up	tʃ^{h}ɛintʃiʌp	2	0	1	1	0	1	0	0	0	1	1	0	0	1
30	chip	tʃ^{h}ip	2	0	1	1	0	1	0	0	0	1	0	1	0	1
31	chop	tʃ^{h}ap, tʃ^{h}op	2	0	1	1	0	1	0	0	0	1	0	1	0	1
32	clarinet	k^{h}ɨllalinɛs	2	0	1	1	0	1	0	0	1	0	1	0	1	0
33	classic	k^{h}ɨllæsik	2	0	1	1	0	1	0	1	0	0	1	0	1	0
34	click	k^{h}ɨllik	2	0	1	1	0	1	0	1	0	0	0	1	0	1
35	clinic	k^{h}ɨllinik	2	0	1	1	0	1	0	1	0	0	1	0	1	0
36	clip	k^{h}ɨllip	2	0	1	1	0	1	0	0	0	1	0	1	0	1
37	close-up	k^{h}ɨllotʃɨʌp	2	0	1	1	0	1	0	0	0	1	1	0	1	0
38	club	k^{h}ɨllʌp	2	0	1	1	0	0	1	0	0	1	0	1	0	1
39	coconut	k^{h}ok^{h}onʌs	2	0	1	1	0	1	0	0	1	0	1	0	1	0
40	comeback	k^{h}ʌmpæk	2	0	1	1	0	1	0	1	0	0	1	0	1	0
41	comic	k^{h}omik	2	0	1	1	0	1	0	1	0	0	1	0	1	0
42	cosmetic	k^{h}osɨmɛt^{h}ik	2	0	1	1	0	1	0	1	0	0	1	0	1	0
43	crack	k^{h}ɨlæk	2	0	1	1	0	1	0	1	0	0	0	1	0	1
44	cricket	k^{h}ɨlikɛs	2	0	1	1	0	1	0	0	1	0	1	0	1	0
45	cup	k^{h}ʌp	2	0	1	1	0	1	0	0	0	1	0	1	0	1
46	desktop	tɛsɨk^{h}ɨt^{h}ap, tɛsɨk^{h}ɨt^{h}op	2	0	1	1	0	1	0	0	0	1	1	0	1	0
47	dip	tip	2	0	1	1	0	1	0	0	0	1	0	1	0	1
48	diskette	tisk^{h}ɛs	2	0	1	1	0	1	0	0	1	0	1	0	0	1
49	dugout	tʌkaus, tʌkɨaus	2	0	1	0	1	1	0	0	1	0	1	0	1	0
50	doughnut	tonʌt	2	0	1	1	0	1	0	0	1	0	1	0	1	0
51	dramatic	tɨlamat^{h}ik	2	0	1	1	0	1	0	1	0	0	1	0	1	0
52	drug	tɨlʌk	2	0	1	1	0	0	1	1	0	0	0	1	0	1
53	duck	tʌk	2	0	1	1	0	1	0	1	0	0	0	1	0	1
54	duet	tjuɛs	2	0	1	1	0	1	0	0	1	0	1	0	0	1
55	dynamic	tainamik	2	0	1	1	0	1	0	1	0	0	1	0	1	0
56	economic	ik^{h}onomik	2	0	1	1	0	1	0	1	0	0	1	0	1	0
57	electric	illɛkt^{h}ɨlik	2	0	1	1	0	1	0	1	0	0	1	0	1	0
58	erotic	ɛlot^{h}ik	2	0	1	1	0	1	0	1	0	0	1	0	1	0
59	ethnic	ɛsɨnik	2	0	1	1	0	1	0	1	0	0	1	0	1	0
60	Europe	julʌp	2	0	1	1	0	1	0	0	0	1	1	0	1	0
61	fade-out	p^{h}ɛitɨaus	2	0	1	0	1	1	0	0	1	0	1	0	1	0
62	fantastic	p^{h}ant^{h}ast^{h}ik	2	0	1	1	0	1	0	0	1	0	1	0	1	0
63	feedback	p^{h}itɨpæk	2	0	1	1	0	1	0	1	0	0	1	0	1	0
64	flat	p^{h}llæs	2	0	1	1	0	1	0	0	1	0	0	1	0	1
65	format	p^{h}omæs	2	0	1	1	0	1	0	0	1	0	1	0	1	0
66	fullback	p^{h}ulpæk	2	0	1	1	0	1	0	1	0	0	1	0	1	0
67	gadget	katʃɛs	2	0	1	1	0	1	0	0	1	0	1	0	1	0
68	gallop	kællʌp	2	0	1	1	0	1	0	0	0	1	1	0	1	0
69	gap	kæp	2	0	1	1	0	1	0	0	0	1	0	1	0	1
70	garnet	kanɛs	2	0	1	1	0	1	0	0	1	0	1	0	1	0

71	geographic	tʃiokɨlapʰik	2	0	1	1	0	1	0	1	0	0	1	0	1	0
72	God	kas	2	0	1	0	1	0	1	0	1	0	0	1	0	1
73	gossip	kasip	2	0	1	1	0	1	0	0	0	1	1	0	1	0
74	go-stop	kosɨtʰop	2	0	1	1	0	1	0	0	0	1	1	0	0	1
75	Gothic	kotik	2	0	1	1	0	1	0	1	0	0	1	0	1	0
76	graphic	kɨlæpʰik	2	0	1	1	0	1	0	1	0	0	1	0	1	0
77	grip	kɨlip	2	0	1	1	0	1	0	0	0	1	0	1	0	1
78	group	kɨlup	2	0	1	0	1	1	0	0	0	1	0	1	0	1
79	guidebook	kaitɨpuk	2	0	1	1	0	1	0	1	0	0	1	0	0	1
80	halfback	hapʰɨpæk	2	0	1	1	0	1	0	1	0	0	1	0	1	0
81	handbag	hæntɨpæk	2	0	1	1	0	0	1	1	0	0	1	0	1	0
82	handbook	hæntɨpuk	2	0	1	1	0	1	0	1	0	0	1	0	1	0
83	handicap	hæntikʰæp	2	0	1	1	0	1	0	0	0	1	1	0	1	0
84	helmet	hɛlmɛs	2	0	1	1	0	1	0	0	1	0	1	0	1	0
85	hip-hop	hiphap	2	0	1	1	0	1	0	0	0	1	1	0	0	1
86	Hispanic	hisɨpænik	2	0	1	1	0	1	0	1	0	0	1	0	1	0
87	hot	has	2	0	1	1	0	1	0	0	1	0	0	1	0	1
88	inkjet	iŋkʰɨtʃɛs	2	0	1	1	0	1	0	0	1	0	1	0	0	1
89	internet	intʰʌnɛs	2	0	1	1	0	1	0	0	1	0	1	0	1	0
90	isometric	isomɛtʰɨlik	2	0	1	1	0	1	0	1	0	0	1	0	1	0
91	jab	tʃæp	2	0	1	1	0	0	1	0	0	1	0	1	0	1
92	jacket	tʃakʰɛs	2	0	1	1	0	1	0	0	1	0	1	0	1	0
93	job	tʃap	2	0	1	1	0	0	1	0	0	1	0	1	0	1
94	joystick	tʃoisɨtʰik	2	0	1	1	0	1	0	1	0	0	1	0	1	0
95	kayak	kʰajak	2	0	1	1	0	1	0	1	0	0	1	0	1	0
96	ketchup	kʰɛtʃʰʌp	2	0	1	1	0	1	0	0	0	1	1	0	1	0
97	kick	kʰik	2	0	1	1	0	1	0	1	0	0	0	1	0	1
98	lab	læp	2	0	1	1	0	0	1	0	0	1	0	1	0	1
99	lap	læp	2	0	1	1	0	1	0	0	0	1	0	1	0	1
100	laptop	læptap	2	0	1	1	0	1	0	0	0	1	1	0	1	0
101	Lasik	lasik	2	0	1	1	0	1	0	1	0	0	1	0	1	0
102	layout	lɛiaus	2	0	1	0	1	1	0	0	1	0	1	0	1	0
103	lay-up	lɛiʌp	2	0	1	1	0	1	0	0	0	1	1	0	1	0
104	leadership	litʌsip	2	0	1	1	0	1	0	0	0	1	1	0	1	0
105	lib	lip	2	0	1	1	0	0	1	0	0	1	0	1	0	1
106	lilac	laillak	2	0	1	1	0	1	0	1	0	0	1	0	1	0
107	lineup	lainʌp	2	0	1	1	0	1	0	0	0	1	1	0	1	0
108	lipstick	lipsɨtʰik	2	0	1	1	0	1	0	1	0	0	1	0	1	0
109	logout	lokɨaus	2	0	1	0	1	1	0	0	1	0	1	0	1	0
110	look	luk	2	0	1	1	0	1	0	1	0	0	0	1	0	1
111	magic	mætʃik	2	0	1	1	0	1	0	1	0	0	1	0	1	0
112	magnetic	makɨnɛtʰik	2	0	1	1	0	1	0	1	0	0	1	0	1	0
113	make-up	mɛikʰɨʌp	2	0	1	1	0	1	0	0	0	1	1	0	1	0
114	map	mæp	2	0	1	1	0	1	0	0	0	1	0	1	0	1
115	market	makʰɛs	2	0	1	1	0	1	0	0	1	0	1	0	1	0
116	membership	mɛmpʌsip	2	0	1	1	0	1	0	0	0	1	1	0	1	0
117	metalic	mɛtʰallik	2	0	1	1	0	1	0	1	0	0	1	0	1	0
118	microchip	maikʰɨlotʃʰip	2	0	1	1	0	1	0	0	0	1	1	0	1	0
119	music	mjutʃik	2	0	1	1	0	1	0	1	0	0	1	0	1	0
120	NASDAQ	nasɨtak	2	0	1	1	0	1	0	1	0	0	1	0	1	0
121	net	nɛs	2	0	1	1	0	1	0	0	1	0	0	1	0	1
122	netbook	nɛspuk	2	0	1	1	0	1	0	1	0	0	1	0	1	0
123	netiquette	nɛtʰikʰɛs	2	0	1	1	0	1	0	0	1	0	1	0	1	0
124	net top	nɛstʰap	2	0	1	1	0	1	0	0	0	1	1	0	1	0
125	nightclub	naitʰɨkʰɨllʌp	2	0	1	1	0	0	1	0	0	1	1	0	1	0
126	nonstop	nonsɨtʰop, nonsɨtʰap	2	0	1	1	0	1	0	0	0	1	1	0	0	1
127	Nordic	nolɨtik	2	0	1	1	0	1	0	1	0	0	1	0	1	0
128	notebook	notʰɨpuk	2	0	1	1	0	1	0	1	0	0	1	0	1	0
129	Olympic	ollimpʰik	2	0	1	1	0	1	0	1	0	0	1	0	1	0
130	omelet	omɨllɛs	2	0	1	1	0	1	0	0	1	0	1	0	1	0
131	out	aus	2	0	1	0	1	1	0	0	1	0	0	1	0	1
132	outlet	auslɛs, aullɛs	2	0	1	1	0	1	0	0	1	0	1	0	1	0
133	output	auspʰus	2	0	1	1	0	1	0	0	1	0	1	0	1	0
134	overlap	opʌlæp	2	0	1	1	0	1	0	0	0	1	1	0	1	0
135	pack	pʰæk	2	0	1	1	0	1	0	1	0	0	0	1	0	1
136	packet	pʰækʰit	2	0	1	1	0	1	0	0	1	0	1	0	1	0
137	panic	pʰænik	2	0	1	1	0	1	0	1	0	0	1	0	1	0
138	partnership	pʰatʰɨnʌsip	2	0	1	1	0	1	0	0	0	1	1	0	1	0
139	philharmonic	pʰilhamonik	2	0	1	1	0	1	0	1	0	0	1	0	1	0
140	photogenic	pʰotʰotʃɛnik	2	0	1	1	0	1	0	1	0	0	1	0	1	0

141	photoshop	p^{h}ot^{h}osjap, p^{h}ot^{h}osjop	2	0	1	1	0	1	0	0	0	1	1	0	1	0
142	picket	p^{h}ik^{h}ɛs	2	0	1	1	0	1	0	0	1	0	1	0	1	0
143	pick-up	p^{h}ikʌp	2	0	1	1	0	1	0	0	0	1	1	0	1	0
144	picnic	p^{h}ik^{h}ɨnik	2	0	1	1	0	1	0	1	0	0	1	0	1	0
145	pilot	paillʌs	2	0	1	1	0	1	0	0	1	0	1	0	1	0
146	pitchout	p^{h}itʃ^{h}iaus	2	0	1	0	1	1	0	0	1	0	1	0	1	0
147	plastic	p^{h}ɨllasɨt^{h}ik	2	0	1	1	0	1	0	1	0	0	1	0	1	0
148	Platonic	p^{h}ɨllat^{h}onik	2	0	1	1	0	1	0	1	0	0	1	0	1	0
149	plot	p^{h}ɨllot, p^{h}ɨllat	2	0	1	1	0	1	0	0	1	0	0	1	0	1
150	pocket	p^{h}ok^{h}ɛs	2	0	1	1	0	1	0	0	1	0	1	0	1	0
151	politic	p^{h}ollit^{h}ik	2	0	1	1	0	1	0	1	0	0	1	0	1	0
152	polyp	p^{h}ollip	2	0	1	1	0	1	0	0	0	1	1	0	1	0
153	pop	p^{h}ap	2	0	1	1	0	1	0	0	0	1	0	1	0	1
154	pub	p^{h}ʌp	2	0	1	1	0	0	1	0	0	1	0	1	0	1
155	public	p^{h}ʌpɨllik	2	0	1	1	0	1	0	1	0	0	1	0	1	0
156	quick	k^{h}wik	2	0	1	1	0	1	0	1	0	0	0	1	0	1
157	rap	læp	2	0	1	1	0	1	0	0	0	1	0	1	0	1
158	restaurant	lɛsɨt^{h}olaŋ	2	0	1	1	0	1	0	0	1	0	1	0	1	0
159	rock	lak	2	0	1	1	0	1	0	1	0	0	0	1	0	1
160	romantic	lomænt^{h}ik	2	0	1	1	0	1	0	1	0	0	1	0	1	0
161	sack	sæk	2	0	1	1	0	1	0	1	0	0	0	1	0	1
162	scrap	sɨk^{h}ɨlæp	2	0	1	1	0	1	0	0	0	1	0	1	0	1
163	scrapbook	sɨk^{h}ɨlæppuk	2	0	1	1	0	1	0	1	0	0	1	0	1	0
164	set-up	sɛsʌp	2	0	1	1	0	1	0	0	0	1	1	0	1	0
165	shop	sjop, sjap	2	0	1	1	0	1	0	0	0	1	0	1	0	1
166	shot	sjas	2	0	1	1	0	1	0	0	1	0	0	1	0	1
167	showmanship	sjomænsip	2	0	1	1	0	1	0	0	0	1	1	0	1	0
168	shutout	sjʌsaus	2	0	1	0	1	1	0	0	1	0	1	0	1	0
169	shuttlecock	sjʌt^{h}ɨlk^{h}ok	2	0	1	1	0	1	0	1	0	0	1	0	1	0
170	sidekick	saitɨk^{h}ik	2	0	1	1	0	1	0	1	0	0	1	0	1	0
171	sitemap	sait^{h}ɨmæp	2	0	1	1	0	1	0	0	0	1	1	0	1	0
172	skinship	sɨk^{h}insip	2	0	1	1	0	1	0	0	0	1	1	0	1	0
173	skip	sɨk^{h}ip	2	0	1	1	0	1	0	0	0	1	0	1	0	1
174	slap	sɨllæp	2	0	1	1	0	1	0	0	0	1	0	1	0	1
175	slavic	sɨllapik	2	0	1	1	0	1	0	1	0	0	1	0	1	0
176	slip	sɨllip	2	0	1	1	0	1	0	0	0	1	0	1	0	1
177	slot	sɨllas, sɨllos	2	0	1	1	0	1	0	0	1	0	0	1	0	1
178	snack	sɨnæk	2	0	1	1	0	1	0	1	0	0	0	1	0	1
179	snap	sɨnæp	2	0	1	1	0	1	0	0	0	1	0	1	0	1
180	socket	sok^{h}ɛs	2	0	1	1	0	1	0	0	1	0	1	0	1	0
181	sponsorship	sɨp^{h}onsʌsip	2	0	1	1	0	1	0	0	0	1	1	0	1	0
182	sportsmanship	sɨp^{h}otʃ^{h}ɨmænsip	2	0	1	1	0	1	0	0	0	1	1	0	1	0
183	step	sɨt^{h}ɛp	2	0	1	1	0	1	0	0	0	1	0	1	0	1
184	stick	sɨt^{h}ik	2	0	1	1	0	1	0	1	0	0	0	1	0	1
185	stop	sɨt^{h}op	2	0	1	1	0	1	0	0	0	1	0	1	0	1
186	strikeout	sɨt^{h}ɨlaik^{h}ɨaus	2	0	1	1	0	1	0	0	1	0	1	0	1	0
187	supermarket	sjup^{h}ʌmak^{h}ɛs	2	0	1	1	0	1	0	0	1	0	1	0	1	0
188	symphonic	simp^{h}onik	2	0	1	1	0	1	0	1	0	0	1	0	1	0
189	tab	t^{h}æp	2	0	1	1	0	0	1	0	0	1	0	1	0	1
190	tap	t^{h}æp	2	0	1	1	0	0	1	0	0	1	0	1	0	1
191	target	t^{h}akɛs	2	0	1	1	0	1	0	0	1	0	1	0	1	0
192	technique	t^{h}ɛk^{h}ɨnik	2	0	1	1	0	1	0	1	0	0	1	0	1	0
193	templet	t^{h}ɛmp^{h}ɨlis	2	0	1	1	0	1	0	0	1	0	1	0	1	0
194	ticket	t^{h}ik^{h}ɛs	2	0	1	1	0	1	0	0	1	0	1	0	1	0
195	tip	t^{h}ip	2	0	1	1	0	1	0	0	0	1	0	1	1	0
196	TOEIC	t^{h}oik	2	0	1	1	0	1	0	1	0	0	1	0	1	0
197	top	t^{h}ap, t^{h}op	2	0	1	1	0	1	0	0	0	1	0	1	0	1
198	topic	t^{h}op^{h}ik	2	0	1	1	0	1	0	1	0	0	1	0	1	0
199	track	t^{h}ɨlæk	2	0	1	1	0	1	0	1	0	0	0	1	0	1
200	trap	t^{h}ɨlæp	2	0	1	1	0	1	0	0	0	1	0	1	0	1
201	trek	t^{h}ɨlæk	2	0	1	1	0	1	0	1	0	0	0	1	0	1
202	trick	t^{h}ɨlik	2	0	1	1	0	1	0	1	0	0	0	1	0	1
203	truck	t^{h}ɨlʌk	2	0	1	1	0	1	0	1	0	0	0	1	0	1
204	trumpet	t^{h}ɨlʌmp^{h}ɛs	2	0	1	1	0	1	0	0	1	0	1	0	1	0
205	tulip	t^{h}julip	2	0	1	1	0	1	0	0	0	1	1	0	1	0
206	typographic	t^{h}aip^{h}okɨlap^{h}ik	2	0	1	1	0	1	0	1	0	0	1	0	1	0
207	ultraviolet	ult^{h}ɨlapaiollɛs	2	0	1	1	0	1	0	0	1	0	1	0	1	0
208	up	ʌp	2	0	1	1	0	1	0	0	0	1	0	1	0	1
209	velvet	pɛlpɛs	2	0	1	1	0	1	0	0	1	0	1	0	1	0
210	warming-up	wʌmiŋʌp	2	0	1	1	0	1	0	0	0	1	1	0	0	1
211	web	wɛp	2	0	1	1	0	0	1	0	0	1	0	1	0	1
212	wind-up	waintɨʌp	2	0	1	1	0	1	0	0	0	1	1	0	1	0
213	workshop	wʌk^{h}ɨsjop	2	0	1	1	0	1	0	0	0	1	1	0	1	0
214	wrap	læp	2	0	1	1	0	1	0	0	0	1	0	1	0	1

Class 3: Optional vowel insertion

No.	English word	Korean form	Class	V	C	Vowel_L	Vowel_T	Stop_VL	Stop_VD	PoA_DOR	PoA_COR	PoA_LAB	Syllables_P	Syllables_M	Stress_N	Stress
1	APEC	ɛip^{h}ɛk, ɛip^{h}ɛk^{h}ɨ	3	1	1	1	0	1	0	1	0	0	1	0	1	0
2	bonnet	ponis, ponnɛs, ponnit^{h}ɨ	3	1	1	1	0	1	0	0	1	0	1	0	1	0
3	boycott	poik^{h}os, poik^{h}ot^{h}ɨ	3	1	1	1	0	1	0	0	1	0	1	0	1	0
4	bulldog	pultok, pultokɨ	3	1	1	1	0	0	1	1	0	0	1	0	1	0
5	cake	k^{h}ɛik, k^{h}ɛik^{h}ɨ	3	1	1	0	1	1	0	0	1	0	0	1	0	1
6	carpet	k^{h}ap^{h}ɛs, k^{h}ap^{h}ɛt^{h}ɨ	3	1	1	1	0	1	0	0	1	0	1	0	1	0
7	cassette	k^{h}asɛs, k^{h}asɛt^{h}ɨ	3	1	1	1	0	1	0	0	1	0	1	0	1	0
8	catalogue	k^{h}at^{h}alok, k^{h}at^{h}alokɨ	3	1	1	1	0	0	1	1	0	0	1	0	1	0
9	check	tʃ^{h}ɛk, tʃ^{h}ɛk^{h}ɨ	3	1	1	1	0	1	0	1	0	0	0	1	0	1
10	chocolate	tʃ^{h}ok^{h}ollis, ts^{h}ok^{h}ollɛs, tʃ^{h}ok^{h}olɛt^{h}ɨ	3	1	1	1	0	1	0	0	1	0	1	0	1	0
11	concept	k^{h}ʌnsɛp, k^{h}ʌnsɛpt^{h}ɨ	3	1	1	1	0	1	0	0	1	0	1	0	1	0
12	cook	k^{h}uk, k^{h}uk^{h}ɨ	3	1	1	1	0	1	0	1	0	0	0	1	0	1
13	cornet	k^{h}onɛs, k^{h}olɨnɛs, k^{h}onɛt^{h}ɨ	3	1	1	1	0	1	0	0	1	0	1	0	1	0
14	credit	k^{h}ɨlɛtis, k^{h}ɨlɛtit^{h}ɨ	3	1	1	1	0	1	0	0	1	0	1	0	1	0
15	Cupid	k^{h}jupis, k^{h}jupit^{h}ɨ	3	1	1	1	0	0	1	0	1	0	1	0	1	0
16	cut	k^{h}ʌs, k^{h}ʌt^{h}ɨ	3	1	1	1	0	1	0	0	1	0	0	1	0	1
17	deck	tɛk, tɛk^{h}ɨ	3	1	1	1	0	1	0	1	0	0	0	1	0	1
18	delicate	tɛllik^{h}is, tɛllik^{h}it^{h}ɨ	3	1	1	1	0	1	0	0	1	0	1	0	1	0
19	dog	tok, tokɨ	3	1	1	0	1	0	1	1	0	0	0	1	0	1
20	dot	tas, tat^{h}ɨ, tot^{h}ɨ	3	1	1	1	0	1	0	0	1	0	0	1	0	1
21	eight	ɛis, ɛit^{h}ɨ	3	1	1	0	1	1	0	0	1	0	0	1	0	1
22	feet	p^{h}is, p^{h}it^{h}ɨ	3	1	1	0	1	1	0	0	1	0	0	1	0	1
23	fight	p^{h}ais, p^{h}ait^{h}ɨ	3	1	1	0	1	1	0	0	1	0	0	1	0	1
24	flute	p^{h}ɨllus, p^{h}ɨllut^{h}ɨ	3	1	1	0	1	1	0	0	1	0	0	1	0	1
25	folk	p^{h}ʌk, p^{h}ok^{h}ɨ	3	1	1	1	0	1	0	1	0	0	0	1	0	1
26	hat	hæs, hæt^{h}ɨ	3	1	1	1	0	1	0	0	1	0	0	1	0	1
27	hip	hip, hip^{h}ɨ	3	1	1	1	0	1	0	0	0	1	0	1	0	1
28	Hollywood	hallius, halliutɨ	3	1	1	1	0	0	1	0	1	0	1	0	1	0
29	hook	hʊk, hʊk^{h}ɨ	3	1	1	1	0	1	0	1	0	0	0	1	0	1
30	jeep	tʃip, tʃip^{h}ɨ	3	1	1	0	1	1	0	0	0	1	0	1	0	1
31	jet	tʃɛs, tʃɛt^{h}ɨ	3	1	1	1	0	1	0	0	1	0	0	1	0	1
32	kit	kis, kit^{h}ɨ	3	1	1	1	0	1	0	0	1	0	0	1	0	1
33	magnet	makɨnɛt, makɨnɛt^{h}ɨ	3	1	1	1	0	1	0	0	1	0	1	0	1	0
34	marmot	malɨmos, malɨmot^{h}ɨ	3	1	1	1	0	1	0	0	1	0	1	0	1	0
35	merit	mɛlis, mɛlit^{h}ɨ	3	1	1	1	0	1	0	0	1	0	1	0	1	0
36	minuet	minjuɛs, minjuɛt^{h}ɨ	3	1	1	1	0	1	0	0	1	0	1	0	0	1
37	moonlight	munlais, munlait^{h}ɨ	3	1	1	0	1	1	0	0	1	0	1	0	1	0
38	neck	nɛk, nɛk^{h}ɨ	3	1	1	1	0	1	0	1	0	0	0	1	0	1
39	net	nɛs, nɛt^{h}ɨ	3	1	1	1	0	1	0	0	1	0	0	1	0	1
40	offset	op^{h}ɨsɛs, opsɛt^{h}ɨ	3	1	1	1	0	1	0	0	1	0	1	0	1	0
41	OPEC	op^{h}ɛk, op^{h}ɛk^{h}ɨ	3	1	1	1	0	1	0	1	0	0	1	0	1	0
42	pamphlet	p^{h}amp^{h}ɨllɛs, p^{h}amp^{h}ɨllɛt^{h}ɨ	3	1	1	1	0	1	0	0	1	0	1	0	1	0
43	pilot	p^{h}aillʌs, p^{h}aillʌt^{h}ɨ	3	1	1	1	0	1	0	0	1	0	1	0	1	0
44	pyramid	p^{h}ilamis, p^{h}ilamit^{h}ɨ	3	1	1	1	0	1	0	0	1	0	1	0	1	0
45	roadwork	lotɨwʌk, lotɨwʌk^{h}ɨ	3	1	1	1	0	1	0	1	0	0	1	0	0	1
46	robot	lopos, lopot^{h}ɨ	3	1	1	1	0	1	0	0	1	0	1	0	1	0
47	rocket	lok^{h}ɛs, lok^{h}ɛt^{h}ɨ	3	1	1	1	0	1	0	0	1	0	1	0	1	0
48	scout	sɨk^{h}aws, sɨk^{h}awt^{h}ɨ	3	1	1	0	1	1	0	0	1	0	0	1	0	1
49	set	sɛs, sɛt^{h}ɨ	3	1	1	1	0	1	0	0	1	0	0	1	0	1
50	sherbet	sjapɛs, sjapɛt^{h}ɨ	3	1	1	1	0	1	0	0	1	0	1	0	1	0
51	soup	sup, sup^{h}ɨ	3	1	1	0	1	1	0	0	0	1	0	1	0	1
52	spirit	sɨp^{h}ilis, sɨp^{h}ilit^{h}ɨ	3	1	1	1	0	1	0	0	1	0	1	0	1	0
53	spot	sɨp^{h}os, sɨp^{h}ot^{h}ɨ	3	1	1	1	0	1	0	0	1	0	0	1	0	1
54	street	sɨt^{h}ɨlis, sɨt^{h}ɨlit^{h}ɨ	3	1	1	0	1	1	0	0	1	0	1	0	0	1
55	summit	sʌmis, sʌmit^{h}ɨ	3	1	1	1	0	1	0	0	1	0	1	0	1	0
56	supermarket	sjup^{h}ʌmak^{h}ɛs, sjup^{h}ʌmak^{h}ɛt^{h}ɨ	3	1	1	1	0	1	0	0	1	0	1	0	1	0
57	tag	t^{h}æk, t^{h}ækɨ	3	1	1	1	0	0	1	1	0	0	0	1	0	1
58	tape	t^{h}eip, t^{h}eip^{h}ɨ	3	1	1	0	1	1	0	0	0	1	0	1	0	1
59	technocrat	t^{h}ɛk^{h}ɨnok^{h}ɨlas, t^{h}ɛk^{h}ɨnok^{h}ɨlat^{h}ɨ	3	1	1	1	0	1	0	0	1	0	1	0	1	0
60	trot	t^{h}ɨlos, t^{h}ɨlot^{h}ɨ	3	1	1	1	0	1	0	0	1	0	0	1	0	1
61	type	taip, taip^{h}ɨ	3	1	1	0	1	1	0	0	0	1	0	1	0	1
62	unit	junis, junit^{h}ɨ	3	1	1	1	0	1	0	0	1	0	0	1	0	1

Appendix 2.

The experimental and filler items used in the production task and the syllable counting task

Experimental items (monosyllables 84 + disyllables 24 + trisyllables 24 = 132)

Place of articulation of final stops				Labials		Coronals		Dorsals	
Voicing of final stops				Voiced	Voiceless	Voiced	Voiceless	Voiced	Voiceless
Monosyllables (84)	Pre-stop vowels	Lax (12)	ɛ	kɛbʰ kɛb̚	kɛpʰ kɛp̚	kɛdʰ kɛd̚	kɛtʰ kɛt̚	fɛgʰ fɛg̚	fɛkʰ fɛk̚
		Tns (72)	u: (12)	vu:bʰ vu:b̚	vu:pʰ vu:p̚	vu:dʰ vu:d̚	vu:tʰ vut̚	vu:gʰ vu:g̚	vu:kʰ vu:k̚
			i: (12)	zi:bʰ zi:b̚	zi:pʰ zi:p̚	zi:dʰ zi:d̚	zi:tʰ zi:t̚	zi:gʰ zi:g̚	zi:kʰ zi:k̚
			aɪ (12)	zaɪbʰ zaɪb̚	zaɪpʰ zaɪp̚	zaɪdʰ zaɪd̚	zaɪtʰ zaɪt̚	zaɪgʰ zaɪg̚	zaɪkʰ zaɪk̚
			eɪ (12)	veɪbʰ veɪb̚	veɪpʰ veɪp̚	veɪdʰ veɪd̚	veɪtʰ veɪt̚	veɪgʰ veɪg̚	veɪkʰ veɪk̚
			oɪ (12)	zoɪbʰ zoɪb̚	zoɪpʰ zoɪp̚	zoɪdʰ zoɪd̚	zoɪtʰ zoɪt̚	zoɪgʰ zoɪg̚	zoɪkʰ zoɪk̚
			oʊ (12)	voʊbʰ voʊb̚	voʊpʰ voʊp̚	voʊdʰ voʊd̚	voʊtʰ voʊt̚	voʊgʰ voʊg̚	voʊkʰ voʊk̚
Disyllables (24)	Stress	Initial (12)		ˈgozɛbʰ ˈgozɛb̚	ˈgozɛpʰ ˈgozɛp̚	ˈgozɛdʰ ˈgozɛd̚	ˈgozɛtʰ ˈgozɛt̚	ˈgozɛgʰ ˈgozɛg̚	ˈgozɛkʰ ˈgozɛk̚
		Final (12)		goˈzɛbʰ goˈzɛb̚	goˈzɛpʰ goˈzɛp̚	goˈzɛdʰ goˈzɛd̚	goˈzɛtʰ goˈzɛt̚	goˈzɛgʰ goˈzɛg̚	goˈzɛkʰ goˈzɛk̚
Trisyllables (24)	Stress	Middle (12)		goˈmozɛbʰ goˈmozɛb̚	goˈmozɛpʰ goˈmozɛp̚	goˈmozɛdʰ goˈmozɛd̚	goˈmozɛtʰ goˈmozɛt̚	goˈmozɛgʰ goˈmozɛg̚	goˈmozɛkʰ goˈmozɛk̚
		Final (12)		ˌgomoˈzɛbʰ ˌgomoˈzɛb̚	ˌgomoˈzɛpʰ ˌgomoˈzɛp̚	ˌgomoˈzɛdʰ ˌgomoˈzɛd̚	ˌgomoˈzɛtʰ ˌgomoˈzɛt̚	ˌgomoˈzɛgʰ ˌgomoˈzɛg̚	ˌgomoˈzɛʰ ˌgomoˈzɛk̚

Filler items (21)

vju:	rju:	kju:	væm	kjæm	fi:θ	vi:θ
sæθ	vɛθ	kɛθ	zɛθ	ˈkrimi	ˈraɪməm	ziki
ˈkikər	ˈmɛpədan	tɛˈmakal	ˈmɛkətan	biˈneɪtəl	zəˈmeɪgal	ˈzɛpənan

Appendix 3. The experimental and filler items used in the categorization experiment

Experimental items (66×3=198)

No.	**Words ending in a consonant** (132)		**Words ending in a vowel** (66)
	Words ending in a released stop (66)	**Words ending in an unreleased stop** (66)	
1	kʰɛtʰ	kʰɛt̚	ˈkʰɛtʰɨ
2	kʰɛdʰ	kʰɛd̚	ˈkʰɛdɨ
3	fɛkʰ	fɛk̚	ˈfɛkʰɨ
4	fɛgʰ	fɛg̚	ˈfɛgɨ
5	kʰɛpʰ	kʰɛp̚	ˈkʰɛpʰɨ
6	kʰɛbʰ	kʰɛb̚	ˈkʰɛbɨ
7	zaɪtʰ	zaɪt̚	ˈzaɪtʰɨ
8	zaɪdʰ	zaɪd̚	ˈzaɪdɨ
9	zaɪkʰ	zaɪk̚	ˈzaɪkʰɨ
10	zaɪgʰ	zaɪg̚	ˈzaɪgɨ
11	zaɪpʰ	zaɪp̚	ˈzaɪpʰɨ
12	zaɪbʰ	zaɪb̚	ˈzaɪbɨ
13	veɪtʰ	veɪt̚	ˈveɪtʰɨ
14	veɪdʰ	veɪd̚	ˈveɪdɨ
15	veɪkʰ	veɪk̚	ˈveɪkʰɨ
16	veɪgʰ	veɪg̚	ˈveɪgɨ
17	veɪpʰ	veɪp̚	ˈveɪpʰɨ
18	veɪbʰ	veɪb̚	ˈveɪbɨ
19	vu:tʰ	vu:t̚	ˈvu:tʰɨ
20	vu:dʰ	vu:d̚	ˈvu:dɨ
21	vu:kʰ	vu:k̚	ˈvu:kʰɨ
22	vu:gʰ	vu:g̚	ˈvu:gɨ
23	vu:pʰ	vu:p̚	ˈvu:pʰɨ
24	vu:bʰ	vu:b̚	ˈvu:bɨ
25	zi:tʰ	zi:t̚	ˈzi:tʰɨ
26	zi:dʰ	zi:d̚	ˈzi:dɨ
27	zi:kʰ	zi:k̚	ˈzi:kʰɨ
28	zi:gʰ	zi:g̚	ˈzi:gɨ
29	zi:pʰ	zi:p̚	ˈzi:pʰɨ
30	zi:bʰ	zi:b̚	ˈzi:bɨ
31	zoɪtʰ	zoɪt̚	ˈzoɪtʰɨ
32	zoɪdʰ	zoɪd̚	ˈzoɪdɨ
33	zoɪkʰ	zoɪk̚	ˈzoɪkʰɨ
34	zoɪgʰ	zoɪg̚	ˈzoɪgɨ

35	zoɪpʰ	zoɪp̚	ˈzoɪpʰɨ
36	zoɪbʰ	zoɪb̚	ˈzoɪbɨ
37	voʊtʰ	voʊt̚	ˈvoʊtʰɨ
38	voʊdʰ	voʊd̚	ˈvoʊdɨ
39	voʊkʰ	voʊk̚	ˈvoʊkʰɨ
40	voʊgʰ	voʊg̚	ˈvoʊgɨ
41	voʊpʰ	voʊp̚	ˈvoʊpʰɨ
42	voʊbʰ	voʊb̚	ˈvoʊbɨ
43	ˈgozɛtʰ	ˈgozɛt̚	ˈgozɛtʰɨ
44	goˈzɛtʰ	goˈzɛt̚	goˈzɛtʰɨ
45	ˈgozɛdʰ	ˈgozɛd̚	ˈgozɛdɨ
46	goˈzɛdʰ	goˈzɛd̚	goˈzɛdɨ
47	ˈgozɛkʰ	ˈgozɛk̚	ˈgozɛkʰɨ
48	goˈzɛkʰ	goˈzɛk̚	goˈzɛkʰɨ
49	ˈgozɛgʰ	ˈgozɛg̚	ˈgozɛgɨ
50	goˈzɛgʰ	goˈzɛg̚	goˈzɛgɨ
51	ˈgozɛpʰ	ˈgozɛp̚	ˈgozɛpʰɨ
52	goˈzɛpʰ	goˈzɛp̚	goˈzɛpʰɨ
53	ˈgozɛbʰ	ˈgozɛb̚	ˈgozɛbɨ
54	goˈzɛbʰ	goˈzɛb̚	goˈzɛbɨ
55	goˈmozɛtʰ	goˈmozɛt̚	goˈmozɛtʰɨ
56	ˌgomoˈzɛtʰ	ˌgomoˈzɛt̚	ˌgomoˈzɛtʰɨ
57	goˈmozɛdʰ	goˈmozɛd̚	goˈmozɛdɨ
58	ˌgomoˈzɛdʰ	ˌgomoˈzɛd̚	ˌgomozɛdɨ
58	goˈmozɛkʰ	goˈmozɛk̚	goˈmozɛkʰɨ
60	ˌgomoˈzɛkʰ	ˌgomoˈzɛk̚	ˌgomoˈzɛkʰɨ
61	goˈmozɛgʰ	goˈmozɛg̚	goˈmozɛgɨ
62	ˌgomoˈzɛgʰ	ˌgomoˈzɛg̚	ˌgomoˈzɛgɨ
63	goˈmozɛpʰ	goˈmozɛp̚	goˈmozɛpʰɨ
64	ˌgomoˈzɛpʰ	ˌgomoˈzɛp̚	ˌgomozɛpʰɨ
65	goˈmozɛbʰ	goˈmozɛb̚	goˈmozɛbɨ
66	ˌgomoˈzɛbʰ	ˌgomoˈzɛb̚	ˌgomoˈzɛbɨ

Filler items (21)

vju:	rju:	kju:	væm	kjæm	fi:θ	vi:θ
sæθ	vɛθ	kɛθ	zɛθ	ˈkrimi	ˈraɪməm	ziki
ˈkikər	ˈmɛpədan	tɛˈmakal	ˈmɛkətan	biˈneɪtəl	zəˈmeɪgal	ˈzɛpənan

Appendix 4. Vowel-final items heard as consonant-final and their responses

No.	Vowel-final words	Voicing	Place	Vowel tenseness	Syllable count	Penultimate stress	'word ends in consonant' response (%)
1	ˈkʰɛtʰɨ	[-voice]	Cor	Lax	2	[+stress]	7%
2	ˈkʰɛdɨ	[+voice]	Cor	Lax	2	[+stress]	3%
3	ˈfɛkʰɨ	[-voice]	Dor	Lax	2	[+stress]	10%
4	ˈfɛgɨ	[+voice]	Dor	Lax	2	[+stress]	3%
5	ˈkʰɛpʰɨ	[-voice]	Lab	Lax	2	[+stress]	10%
6	ˈkʰɛbɨ	[+voice]	Lab	Lax	2	[+stress]	7%
7	ˈzaɪtʰɨ	[-voice]	Cor	Tense	2	[+stress]	3%
8	ˈzaɪdɨ	[+voice]	Cor	Tense	2	[+stress]	0%
9	ˈzaɪkʰɨ	[-voice]	Dor	Tense	2	[+stress]	10%
10	ˈzaɪgɨ	[+voice]	Dor	Tense	2	[+stress]	0%
11	ˈzaɪpʰɨ	[-voice]	Lab	Tense	2	[+stress]	10%
12	ˈzaɪbɨ	[+voice]	Lab	Tense	2	[+stress]	0%
13	ˈveɪtʰɨ	[-voice]	Cor	Tense	2	[+stress]	0%
14	ˈveɪdɨ	[+voice]	Cor	Tense	2	[+stress]	7%
15	ˈveɪkʰɨ	[-voice]	Dor	Tense	2	[+stress]	7%
16	ˈveɪgɨ	[+voice]	Dor	Tense	2	[+stress]	7%
17	ˈveɪpʰɨ	[-voice]	Lab	Tense	2	[+stress]	7%
18	ˈveɪbɨ	[+voice]	Lab	Tense	2	[+stress]	0%
19	ˈvuːtʰɨ	[-voice]	Cor	Tense	2	[+stress]	13%
20	ˈvuːdɨ	[+voice]	Cor	Tense	2	[+stress]	0%
21	ˈvuːkʰɨ	[-voice]	Dor	Tense	2	[+stress]	17%
22	ˈvuːgɨ	[+voice]	Dor	Tense	2	[+stress]	3%
23	ˈvuːpʰɨ	[-voice]	Lab	Tense	2	[+stress]	7%
24	ˈvuːbɨ	[+voice]	Lab	Tense	2	[+stress]	0%
25	ˈziːtʰɨ	[-voice]	Cor	Tense	2	[+stress]	10%
26	ˈziːdɨ	[+voice]	Cor	Tense	2	[+stress]	0%
27	ˈziːkʰɨ	[-voice]	Dor	Tense	2	[+stress]	3%
28	ˈziːgɨ	[+voice]	Dor	Tense	2	[+stress]	3%
29	ˈziːpʰɨ	[-voice]	Lab	Tense	2	[+stress]	7%
30	ˈziːbɨ	[+voice]	Lab	Tense	2	[+stress]	0%
31	ˈzoɪtʰɨ	[-voice]	Cor	Tense	2	[+stress]	3%
32	ˈzoɪdɨ	[+voice]	Cor	Tense	2	[+stress]	3%
33	ˈzoɪkʰɨ	[-voice]	Dor	Tense	2	[+stress]	10%
34	ˈzoɪgɨ	[+voice]	Dor	Tense	2	[+stress]	0%
35	ˈzoɪpʰɨ	[-voice]	Lab	Tense	2	[+stress]	3%
36	ˈzoɪbɨ	[+voice]	Lab	Tense	2	[+stress]	7%

37	ˈvoʊtʰɨ	[-voice]	Cor	Tense	2	[+stress]	3%
38	ˈvoʊdɨ	[+voice]	Cor	Tense	2	[+stress]	3%
39	ˈvoʊkʰɨ	[-voice]	Dor	Tense	2	[+stress]	3%
40	ˈvoʊgɨ	[+voice]	Dor	Tense	2	[+stress]	3%
41	ˈvoʊpʰɨ	[-voice]	Lab	Tense	2	[+stress]	3%
42	ˈvoʊbɨ	[+voice]	Lab	Tense	2	[+stress]	7%
43	ˈgozɛtʰɨ	[-voice]	Cor	Lax	3	[-stress]	7%
44	goˈzɛtʰɨ	[-voice]	Cor	Lax	3	[+stress]	3%
45	ˈgozɛdɨ	[+voice]	Cor	Lax	3	[-stress]	7%
46	goˈzɛdɨ	[+voice]	Cor	Lax	3	[+stress]	7%
47	ˈgozɛkʰɨ	[-voice]	Dor	Lax	3	[-stress]	13%
48	goˈzɛkʰɨ	[-voice]	Dor	Lax	3	[+stress]	3%
49	ˈgozɛgɨ	[+voice]	Dor	Lax	3	[-stress]	13%
50	goˈzɛgɨ	[+voice]	Dor	Lax	3	[+stress]	3%
51	ˈgozɛpʰɨ	[-voice]	Lab	Lax	3	[-stress]	10%
52	goˈzɛpʰɨ	[-voice]	Lab	Lax	3	[+stress]	10%
53	ˈgozɛbɨ	[+voice]	Lab	Lax	3	[-stress]	3%
54	goˈzɛbɨ	[+voice]	Lab	Lax	3	[+stress]	10%
55	goˈmozɛtʰɨ	[-voice]	Cor	Lax	4	[-stress]	7%
56	ˌgomoˈzɛtʰɨ	[-voice]	Cor	Lax	4	[+stress]	10%
57	goˈmozɛdɨ	[+voice]	Cor	Lax	4	[-stress]	7%
58	ˌgomoˈzɛdɨ	[+voice]	Cor	Lax	4	[+stress]	3%
59	goˈmozɛkʰɨ	[-voice]	Dor	Lax	4	[-stress]	3%
60	ˌgomoˈzɛkʰɨ	[-voice]	Dor	Lax	4	[+stress]	10%
61	goˈmozɛgɨ	[+voice]	Dor	Lax	4	[-stress]	0%
62	ˌgomoˈzɛgɨ	[+voice]	Dor	Lax	4	[+stress]	3%
63	goˈmozɛpʰɨ	[-voice]	Lab	Lax	4	[-stress]	13%
64	ˌgomoˈzɛpʰɨ	[-voice]	Lab	Lax	4	[+stress]	17%
65	goˈmozɛbɨ	[+voice]	Lab	Lax	4	[-stress]	7%
66	ˌgomoˈzɛbɨ	[+voice]	Lab	Lax	4	[+stress]	3%
						Mean	**5.7%**
						SD	**4.2%**

Appendix 5. The experimental and filler items used in the similarity judgement experiment

Experimental items (English 132 + Korean 81 (A 27+ B 54) = 213)

No.	**Korean word stimuli with no final vowel** (A=27)	**English word stimuli** (X=132)	**Korean word stimuli with a final vowel** (B=54)
1	켓 k^{h}ɛt˺	k^{h}ɛt^h	케트 k^{h}ɛt^{h}ɨ
2		k^{h}ɛt˺	
3		k^{h}ɛd^h	케드 k^{h}ɛdɨ
4		k^{h}ɛd˺	
5	휏 fɛk˺	fɛk^h	훼크 fɛk^{h}ɨ
6		fɛk˺	
7		fɛg^h	훼그 fɛgɨ
8		fɛg˺	
9	켑 k^{h}ɛp˺	k^{h}ɛp^h	케프 k^{h}ɛp^{h}ɨ
10		k^{h}ɛp˺	
11		k^{h}ɛb^h	케브 k^{h}ɛbɨ
12		k^{h}ɛb˺	
13	자잇 zait˺	zaɪt^h	자이트 zait^{h}ɨ
14		zaɪt˺	
15		zaɪd^h	자이드 zaidɨ
16		zaɪd˺	
17	자익 zaik˺	zaɪk^h	자이크 zaik^{h}ɨ
18		zaɪk˺	
19		zaɪg^h	자이그 zaigɨ
20		zaɪg˺	
21	자입 zaip˺	zaɪp^h	자이프 zaip^{h}ɨ
22		zaɪp˺	
23		zaɪb^h	자이브 zaibɨ
24		zaɪb˺	
25	베잇 veit˺	veɪt^h	베이트 veit^{h}ɨ
26		veɪt˺	
27		veɪd^h	베이드 veidɨ
28		veɪd˺	
29	베익 veik˺	veɪk^h	베이크 veik^{h}ɨ
30		veɪk˺	
31		veɪg^h	베이그 veigɨ
32		veɪg˺	
33	베입 veip˺	veɪp^h	베이프 veip^{h}ɨ
34		veɪp˺	
35		veɪb^h	베이브 veibɨ
36		veɪb˺	
37	붓 vut˺	vu:t^h	부트 vut^{h}ɨ
38		vu:t˺	
39		vu:d^h	

40		vu:d˺	부드 vudɨ
41	북 vuk˺	vu:k^h	부크 vuk^{h}ɨ
42		vu:k˺	
43		vu:g^h	부그 vugɨ
44		vu:g˺	
45	붑 vup˺	vu:p^h	부프 vup^{h}ɨ
46		vu:p˺	
47		vu:b^h	부브 vubɨ
48		vu:b˺	
49	짓 zit˺	zi:t^h	지트 zit^{h}ɨ
50		zi:t˺	
51		zi:d^h	지드 zidɨ
52		zi:d˺	
53	직 zik˺	zi:k^h	지크 zik^{h}ɨ
54		zi:k˺	
55		zi:g^h	지그 zigɨ
56		zi:g˺	
57	집 zip˺	zip^h	지프 zip^{h}ɨ
58		zi:p˺	
59		zi:b^h	지브 zibɨ
60		zi:b˺	
61	조잇 zoit˺	zoɪt^h	조이트 zoit^{h}ɨ
62		zoɪt˺	
63		zoɪd^h	조이드 zoidɨ
64		zoɪd˺	
65	조익 zoik˺	zoɪk^h	조이크 zoik^{h}ɨ
66		zoɪk˺	
67		zoɪg^h	조이그 zoigɨ
68		zoɪg˺	
69	조입 zoip˺	zoɪp^h	조이프 zoip^{h}ɨ
70		zoɪp˺	
71		zoɪb^h	조이브 zoibɨ
72		zoɪb˺	
73	보웃 vout˺	voʊt^h	보우트 vout^{h}ɨ
74		voʊt˺	
75		voʊd^h	보우드 voudɨ
76		voʊd˺	
77	보욱 vouk˺	voʊk	보우크 vouk^{h}ɨ
78		voʊk˺	
79		voʊg^h	보우그 vougɨ
80		voʊg˺	
81	보웁 voup˺	voʊp^h	보우프 voup^{h}ɨ
82		voʊp˺	
83		voʊb^h	보우브 voubɨ
84		voʊb˺	
85		ˈgozεt^h	고제트 gozεt^{h}ɨ
86		ˈgozεt˺	

87	고젯 gozɛt˺	goˈzɛtʰ	
88		goˈzɛt˺	
89		ˈgozɛdʰ	고제드 gozɛdɨ
90		ˈgozɛd˺	
91		goˈzɛdʰ	
92		goˈzɛd˺	
93	고젝 gozɛk˺	ˈgozɛkʰ	고제크 gozɛkʰɨ
94		ˈgozɛk˺	
95		goˈzɛkʰ	
96		goˈzɛk˺	
97		ˈgozɛgʰ	고제그 gozɛgɨ
98		ˈgozɛg˺	
99		goˈzɛgʰ	
100		goˈzɛg˺	
101	고젭 gozɛp˺	ˈgozɛpʰ	고제프 gozɛpʰɨ
102		ˈgozɛp˺	
103		goˈzɛpʰ	
104		goˈzɛp˺	
105		ˈgozɛbʰ	고제브 gozɛbɨ
106		ˈgozɛb˺	
107		goˈzɛbʰ	
108		goˈzɛb˺	
109	고모젯 gomozɛt˺	goˈmozɛtʰ	고모제트 gomozɛtʰɨ
110		goˈmozɛt˺	
111		ˌgomoˈzɛtʰ	
112		ˌgomoˈzɛt˺	
113		goˈmozɛdʰ	고모제드 gomozɛdɨ
114		goˈmozɛd˺	
115		ˌgomoˈzɛdʰ	
116		ˌgomoˈzɛd˺	
117	고모젝 gomozɛk˺	goˈmozɛkʰ	고모제크 gomozɛkʰɨ
118		goˈmozɛk˺	
119		ˌgomoˈzɛkʰ	
120		ˌgomoˈzɛk˺	
121		goˈmozɛgʰ	고모제그 gomozɛgɨ
122		goˈmozɛg˺	
123		ˌgomoˈzɛgʰ	
124		ˌgomoˈzɛg˺	
125	고모젭 gomozɛp˺	goˈmozɛpʰ	고모제프 gomozɛpʰɨ
126		goˈmozɛp˺	
127		ˌgomoˈzɛpʰ	
128		ˌgomoˈzɛp˺	
129		goˈmozɛbʰ	

130		goˈmozɛb˺	고모제브 gomozɛbɨ
131		ˌgomoˈzɛbʰ	
132		ˌgomoˈzɛb˺	

Filler items (English 10 + Korean 20 = 30)

Korean nonce words (A)	English nonce words (X)	Korean nonce words (B)
쿠 ku:	kju	큐 kju
제쓰 tsɛs’	zɛθ	젯 zɛt˺
비쓰 vis’	vi:θ	빗 vit˺
류 lju	rju	루 lu:
밤 pam	væm	뱀 pæm
크리미 kʰɨrimi	ˈkrimi	크림 kʰɨrim
라이멈 laɪmʌm	ˈraɪməm	라이맘 laɪmam
키커 kʰikʰʌ	ˈkikər	키컬 kʰikʰʌl
부 pu	vju	뷰 pju
비네이탈 pineɪtʰal	biˈneɪtəl	비네이달 pineɪdal