Lexical and phonological effects on phonological variation in L2 English palatalization*

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Yun, Gwanhi. 2012. Lexical and phonological effects on phonological variation in L2 English palatalization. *Studies in Phonetics, Phonology and Morphology* 18.2. 297-320. This study investigates how Korean L2 speakers produce word-final alveolars placed in the word-boundary palatalization environment in English. The purpose of our research is to see whether they show production variation according to lexical factors such as word frequency and wordhood and phonological factors such as word-final alveolar types, number of syllables of the target words, number of word-final codas, etc. Four possible pronunciation variants were identified for word-final alveolars (canonical, palatalization, deletion, and wrong pronunciation). First, the results showed that like previous studies on L1 production, phonological variation was found for Korean L2 speakers. Specifically, canonical variants were predominant, and then the realization of palatalization was also common, whereas mispronounced variants such as deletion and wrong pronunciation were quite rare. Second, word frequency affected the likelihood of palatalization similar to native speakers of English. Palatalization was found more in high-frequency words than in low-frequency words. Third, wordhood affected the likelihood of palatalization. Fourth, production patterns as well as the likelihood of palatalization were affected by word-final alveolar types. Finally, backness of the vowels preceding word-final alveolars affected the occurrences of palatalized variants. That is, word-final alveolars underwent palatalization immediately following front vowels more frequently than back vowels. These findings suggest that production variability is observed even for L2 speakers as well as for L1 speakers. Furthermore, they provide additional support for the claim that frequency may be encoded in word representation of L2 speakers' mental lexicon. Finally, they revealed that many phonological factors contribute to variability of production of categorical phonological rules by L2 speakers, indicating that listeners might consider lexical and phonological factors to recover speakers' intended words. **(Daegu University)**

Keywords: word frequency, phonological environments, likelihood of palatalization, phonological variation, L2 speakers' production.

1. Introduction

Phonological variation on the realization of phonological rues is a very natural process both for L1 and L2 speakers, and yet interestingly, it rarely poses challenges for listeners. It has been well documented that a multitude of factors, either lexical or phonological, affect the variation of production

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of phonological rules for L1 speakers (lexical frequency, Bush (2001), Ernestus et al. (2006); lexical neighborhood density, Vitevitch (2002), Yun (2010); morphological condition on word final "t/d" deletion, Guy (1980); prosody on schwa deletion and epenthesis, Kuipers and Donselaar (1998); speaking rate on English schwa deletion, Dalby (1986); speakers' sex and age effect on the duration of affixes in Dutch, Pluymaekers et al. (2005)). On the ground of production and perception results, in particular, it has been proposed that lexical factors such as lexical frequency and neighborhood density are critical parameters to organize words in the mental lexicon for L1 speakers (Morrisette and Gierut 2002, Vitevitch 2002).[1] Compared to ample studies on phonological variation for L1 speakers, little research revealed lexical and phonological factors on phonological variation by L2 speakers. Thus the present study investigates frequency and phonological environmental effects on L2 palatalization and describes factors in brief (Bell et al. 2003, Johnson 2004).[2] We will briefly review frequency and phonological environment effects on phonological variation.

1.1 Frequency effects on phonological variation

Lexical frequency has been found to influence not only the likelihood or applicability of categorical phonological rules but also the possible range of variation forms, showing their gradient realization. For instance, Patterson and Connine (2001) found that high-frequency words favored a flapping variant [ɾ] of word-medial /t/ in English over the aspirated variant [t^h] (e.g., *city* [sɪɾɪ], *butter* [bʌɾɚ]).

Dilley and Pitt (2007) investigated regressive assimilation in English through Buckeye Corpus. First, they found that the likelihood of place assimilation showed variation depending on the word-final consonant type (/n/: /d/: /t/ = 73%: 51%: 25%). Furthermore, the range of variation was also affected by lexical frequency. Specifically, more frequent monosyllable function words like *in, can, on, that, just, it* exhibited a wider spectrum of variation forms (e.g., assimilation, deletion, glottalization, canonical form) than less frequent words. Low-frequency words, however, did not undergo place assimilation but instead were mostly realized with an underlying (or canonical) form.

Ernestus et al. (2006) also examined the role of lexical frequency on the likelihood of voicing assimilation in Dutch. They found that high-frequency words underwent complete regressive or progressive voice assimilation, whereas low-frequency words were produced without voice

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1 Word frequency refers to the number of cases where a word is used in a certain corpus, while lexical neighborhood density refers to the number of similar words that differ from a given word in one phoneme by substitution, addition or deletion (Goldrick and Rapp 2007).

2 In the current study, L1 speakers refer specifically to English native speakers, while L2 speakers to Korean learners of English.

assimilation. Such frequency-conditioned likelihood of voice assimilation gave rise to phonological variation. Specifically, 43% of consonant clusters were pronounced as completely voiced, 25% as completely voiced, and 20% as unassimilated. These results were interpreted to suggest that higher-frequency words are pronounced with less articulatory efforts and thus tend to be assimilated more than lower-frequency words.

Cooper and Paccia-Cooper (1980) showed that high-frequency words are more likely to show palatalized [d] before [j] than low-frequency words. Bush (2001) also investigated the correlation between string frequency and the likelihood of palatalization applying across word boundaries in English with corpus data for adults and fifth graders. He found that high-frequency strings like *did you, don't you, would you, last year, what you, put your*, etc. were pronounced with palatalized variants more successfully than low-frequency strings such as *bad you, but yet, eat you, had you, good you, kind you'd*, etc. Building on the findings, it was suggested that the collocated strings with high "correlation strength" due to high-frequency such as *would you* might be stored in lexicon as a single unit and thus are more highly likely to show palatalization than those with low "correlation strength" due to low-frequency such as *good you*. That is, it was given an interesting interpretation that word-boundary palatalization could be replaced with word-internal correspondent, following Chomsky and Halle (1968: 230).

Jurafsky et al. (2001) looked into Switchboard database to examine the probability of final [t/d] deletion in English content words with different frequencies. They found that content words with high-frequency such as *want, just, lot*, *good,* etc. exhibited two times more likelihood of word-final [t/d] deletion than low-frequency words such as *punished, closed, touched, draft*, etc. On top of that, the relative frequency of previous words also affected the likelihood of final [t/d] deletion to the extent that high-frequency previous words caused less deletion in the target words than low-frequency previous words. Furthermore, it was found that the former was produced with 18% shorter duration than the latter.

Numerous previous studies mentioned above suggest that lexical frequency plays a crucial role in the likelihood of phonological rules for L1 speakers' production, giving rise to phonological variation. They also indicate that frequency might be encoded in the word representation with different association strengths. Of interest is the indication that L1 listeners take advantage of frequency-dependent attention load as well as other factors to recognize or restore the speakers' intended words. Building on these previous studies on L1 production, the current study investigates whether lexical frequency effect can be obtained for L2 speakers with respect to the likelihood of palatalization and the potential range of variation.

1.2 Phonological contexts on phonological variation

Since one of the goals in the present investigation is to see the role of phonological environments on the likelihood of palatalization, let us take a brief look at previous studies that handled the effects of morphological or phonological factors on the phonological variations. As mentioned in previous section, Dilley and Pitt (2006) looked into the likelihood of English place assimilation and the range of phonological variation. They found that the pattern of variation differed depending on the word-final target consonants. Specifically, final /d/-words exhibited unassimilated (canonical) forms most (51%), then favored a deleted type (44%), and then assimilation occurred only 5% (e.g., *tad pot*). Words with final /n/ were intact as a canonical form by 73%, and 20% of the tokens were pronounced as assimilated forms. Word-final /t/s were realized mostly as glottal variants (31%) or deleted (37%), whereas assimilation variants were only 7% (e.g., *pot[ʔ] cap*). This finding indicates that types and ranges of variants are also affected by the targets of a phonological rule.

In addition to the type of target segments, phonological environments as well exert an influence on the likelihood of phonological rules. Mitterer and Ernestus (2006) analyzed 300 utterances from spoken corpus in Dutch and revealed that word-final /t/-deletion is affected by preceding and following environments. That is, /t/ was more highly likely to be deleted following /s/ than /n/ and /x/ (18% vs. 3% vs. 5%). Furthermore, it was deleted before obstruents more frequently than before vowels (14 % vs. 3%). Moreover, Raymond et al. (2006) also showed that word-medial /t/ in English is frequently elided when it occurs in the onset of post-stress syllables and follows /n/ (e.g., *cóunter*, *cántaloupe,* etc). However, it was not deleted when the following vowel is not reduced but realized as a full vowel (e.g., *context, contact*, etc). Finally, Pitt (2009) performed a similar analysis to see the variation pattern for word-medial /t/ in disyllabic English words. It was shown that deletion occurred 75%, canonical form /t/ 5%, glottal variants 6%, and changes to /d/ 7% when the second syllable contained a reduced vowel (e.g., *center, counter, plenty*, etc). On the other hand, when the vowel of the second syllable was a full vowel, only 11 % was deleted, and 65% was realized as a canonical (underlying) form [t]. Pitt suggested that the application of a phonological rule like /t/-deletion is sensitive to phonological environments.

In sum, the applicability of phonological rules and the range of phonological variations are sensitive to a multitude of lexical and phonological factors as illustrated above in phonological rules across languages. Such wide phonological variation requires listeners to take into consideration many variables such as lexical frequency, morphological environments, and phonological environments in order to successfully recover speakers' intended words (Dilley and Pitt 2007, Gaskell and Marslen-Wilson 1998).

1.3 Research questions

Despite of a great bulk of phonological variation for L1 speakers, much attention has not been paid to L2 speakers' applicability of phonological rules in their target L2 and the potential type or range of phonological variation. Thus the current study attempts to build on prior research on L1 phonological variation and to focus on what patterns of phonological variation emerge for L2 speakers.

First, one goal of the present investigation is to see whether lexical frequency plays a role in Korean L2 speakers' pronunciation variation for English palatalization. Moreover, we attempt to explore what type or range of variants emerges to what extent in their production. If it is found that the likelihood of palatalization varies depending on frequency, it might provide additional support for the assertion that frequency information is encoded in or associated with word representation with different strength according to the degree of frequency even for L2 speakers as well as for L1 speakers (Bybee and Hopper 2001, Luce and Pisoni 1998). Korean palatalization differs from English palatalization in that the former obligatorily occurs solely across morpheme boundaries, whereas the latter takes place obligatorily for morpheme-boundary case (e.g., *expre<u>ssi</u>on*) but word-boundary palatalization is optional (e.g., *di<u>d</u> <u>y</u>ou*). Thus, it might be worthwhile to investigate how/whether Korean L2 speakers realize English optional word-boundary palatalization.

Second, the current study explores whether Korean L2 speakers' variation is sensitive to phonological environments centering on palatalization such as the number of syllables, the type of trigger consonants, the number of codas, etc. This question addresses the issue of whether phonological environments might be universal constraints working for the application of phonological rules. Since there have been few studies on the role of phonological environments on the likelihood of palatalization even for L1 speakers, the results in our study will shed new insights on the patterns for L2 speakers.

This paper is organized as follows. Section 2 explicates an acoustic experiment along with subjects, materials, and procedures and reports results. In Section 3, the likelihood of palatalization and emerging patterns of its production by Korean L2 learners are discussed and section 4 concludes the paper.

2. Experiment: Acoustic Study

2.1 Subjects

Forty English-learning Korean speakers participated in the production experiment. They were all junior or senior undergraduate students and majored in English at Department of English in Daegu University. Thus presumably they had reasonable competence in English. They were all the users of North Gyeongsang dialect in Korean. Twenty five females and fifteen males participated in the production of English words. They ranged in age from 21 to 28 years, with an average age of 23. They had varied amount of exposure to English and all of them had 2 to 16 years of formal English instruction through middle school, high school and college. Their self-evaluated proficiency was average 5 out of ten, ranging from 3 to 7. One subject did not fill in his self-rating proficiency level, and five did not report their TOEIC scores because they did not take the test before. Their TOEIC scores were average 657, ranging from 315 to 920. Taking into self-evaluated proficiency and official TOEIC scores, they seem to be of intermediate-level in English. Subject information is summarized in Table I below.

Table 1. Korean speakers' English learning background

	No.	Mean	Min	Max	SD
Age	40	23	21	28	1.5
Length of English Study	40	10	2	16	3.6
Self-rating proficiency	39	5	3	7	1.2
TOEIC score	35	657	315	920	160

2.2 Stimuli

In order to obtain production materials, 192 test words were extracted from the book which listed real English words with type and token frequency on the basis of the British National Corpus (Leech et al. 2001).[3] All were mono-, di-, or tri-syllabic in length (See the sample words in the Appendix). Half of the test words were classified as low-frequency items (token frequency 1~50), and the other half as high-frequency ones (>50) as illustrated in Table 2.[4]

[3] The British National Corpus (BNC) contains around 100 million words of spoken and written British English. Approximately 90 % comes from written data and 10 % is spoken data. BNC consists of 4,124 different text files and a majority of texts include contemporary English data from the period 1985-1994 (Leech et al. 2001).

[4] The criteria by which words can be divided into high- and low-frequency are not absolute but rather subjective or relative. The present study adopted frequency 50, following Imai et al. (2005). Furthermore, we assume that word frequency used in the present study and elicited from BNC reflects native speakers' subjective frequency, following previous research showing high correlation between those two (Shatzman and Schiller 2004). However, as pointed out by a reviewer, it is still hard to match L1 frequency encoded in BNC with subjective frequency which L2 Korean learners might have been exposed to during formal English education.

Table 2. Mean word frequency of test words
(token frequency refers to occurrences per million words)

WF	Example	Mean	N	Min	Max	SD
LF	"beat"	10	96	0	45	10.3
HF	"meet"	605	96	50	26817	2915

All the words were divided into four groups according to the word-final consonant type (/t, d, s, z/) to see the effect of target consonant type on the likelihood of palatalization. Moreover, both the frequency groups contained twelve vowels in the final syllables, such as /i, ɪ, ɛ, æ, u, ʊ, aʊ, o, ɔ, ɑ, aɪ, ʌ/. Furthermore, all the items differed in the number of word-final consonants, i.e. one, two or three consonants (e.g., *treat, print, resolves*). In sum, all the test items were different according to word frequency and four other phonological factors such as (i) word-final consonant type (/t, d, s, z/), (ii) number of syllables (mono-, di-, tri-), (iii), number of word-final consonants (single, double, triple), and (iv) 12 vowel types in word-final syllable.

In order to explore the wordhood effect on the likelihood of palatalization, 10 nonce-words were added for control items ending with /t, d/ (e.g., *keet, gwit, swate, pwet, kwat, woot, nood, zoat, poht, maht*). Finally, additional eight words were employed as fillers. Taken together, 210 words, all told, were presented to the subjects. Thus, a total of 8400 stimuli were obtained and analyzed (210 tokens × 40 subjects).

2.3 Procedures

Since this study focuses attention on word-boundary palatalization, all the target words ending with an alveolar (/t, d, s, z/) are immediately followed by a word beginning with a triggering palatal /j/ such as "you/your". In order to elicit natural pronunciations, all the two-word sequences were contained in the carrier phrases or sentences where the word-target expressions are preceded by a mono-syllabic article or pronoun and followed by a mono-syllabic word such as "too, do, land, etc.) (e.g., "He *pops you*, too", "I *choose you*, too", "He *pulls you*, too", "I *support you*, too", etc). All the sentences with target words were randomly mixed with sentences with eight filler words. The forty Korean learners of English were instructed to read the sentences one time at a normal and comfortable speed in a quiet phonetics room through a microphone attached a computer. They were not explicitly asked to read the phrases with the application of palatalization. They were recorded through PRAAT (Boersma and Weenink 2009) and the sentences were digitized at a 4.4 kHz sampling rate. On average, the entire experiment lasted about 30 min.

In order to see if the word-final target alveolars were palatalized, phonetic transcriptions were made by two trained phoneticians, who were paid for labeling. One labeler relied on spectrograms and waveforms and perceived the target segments. The target segments present in the speech were judged and labeled as four pronunciation categories such as palatalized (assimilated), canonical (underlying), deleted, and wrong. Deletion variants and wrong forms can be grouped into 'mispronounced variants', but we divided these into two to describe the variation in more detail. The other phonetician measured the approximate central noise energy to check if the segments were palatalized. The segment with overall noise frequency extending below 3,600 Hz down to 2,500 Hz was transcribed as palatalized [ʃ, ʒ, tʃ, dʒ] as described in Ladefoged (2006: 194). The labeler judged a segment to be deleted when she could not hear that sound while playing in the PRAAT. Moreover, the segment was perceived to be canonical when the underlying alveolars (/t, d, s, z/) were still present and unassimilated. Finally, the segment was judged to be wrong or mispronounced when the targets were pronounced as different segments from the underlying alveolars or palatalized sounds. The percentages of each of the four production patterns were calculated for each of the forty participants to fit for repeated-measures ANOVA. Figure 1 illustrates sample spectrograms of each production pattern.

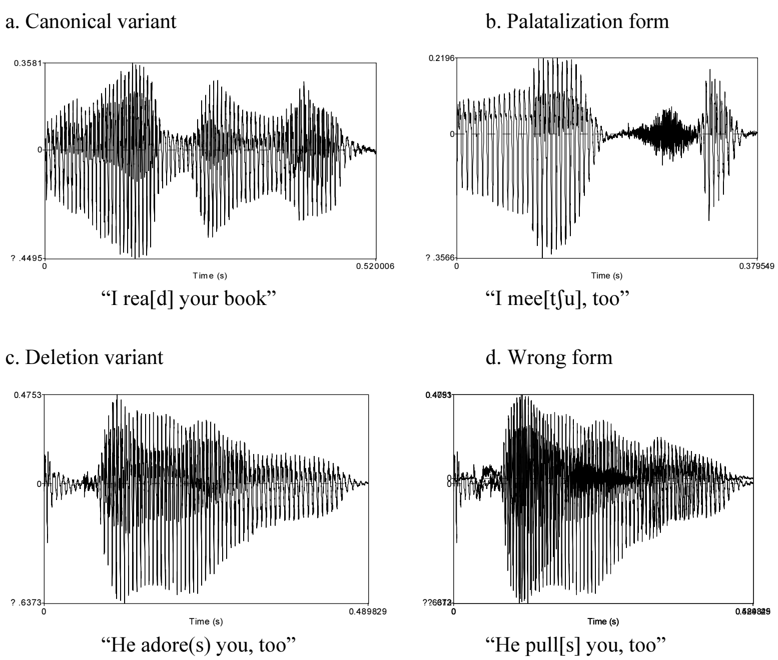

Figure 1. Waveforms of production samples

Since the average percentage of each production pattern was examined within subjects, and the number of labeled types was repeatedly calculated, they were subjected to a one-way repeated-measures ANOVA. Furthermore, in order to see the interaction of lexical frequency factor or each of the phonological environment factor and production type, 2 way repeated-measures ANOVA was performed by PASW (SPSS) Statistics 18. The results of analyses are described as significant if $p<.05$, highly significant if $p<.01$, and approaching marginal significance if $.05<p<.10$ on the basis of significance level $\alpha=5\%$.

2.4 Results

2.4.1 Lexical frequency and palatalization

Table 3 shows the average rate of each of four pronunciation variants (canonical, palatalization, deletion, wrong). Regardless of lexical frequency, the most frequent variant was the canonical form, i.e., non-assimilated one, occurring 63.9% of all the tokens. Realization of palatalization was also quite common, amounting to 21.4 %. However, deletions and wrong pronunciations were not common (respectively 9.3% and 8.1%). Productions of nonce words were removed from calculations to see the frequency effect since their frequencies are substantially close to zero.

Such a finding that the percentages of tokens differ across variants indicates that word-final alveolars are not necessarily palatalized across word boundaries as consistent with the earlier findings observed for native speakers of English (Cooper and Paccia-Cooper 1980, Bush 2001). A relatively higher percentage of the non-assimilated variants also suggest that the application of phonological rules like palatalization is not obligatory but its likelihood may be affected by a multitude of factors.

The average rates of each variant were submitted to a two-way (2×4) repeated-measures ANOVA with frequency (low vs. high) and production type as within-subject factors. Analysis exhibited that there were no main effect of word frequency ($F(1,31)=1.07$, $p>0.05$), and no interaction of frequency and variant type ($F(3,93)=2.02$, $p>0.05$). There was, however, a significant main effect of production type ($F(3,93)=88$, $p<0.001$).

Next, in order to see if four production patterns are different by frequency condition, chi-square test was performed. Analysis showed that the overall variant patterns were significantly different by frequency (X^2(df3)=83.1, $p<0.001$). This result might be due to the striking difference in the rates of palatalization tokens depending on frequency.

Table 3. Frequency effects on palatalization and other variation patterns

Freq.	Production types (%)			
	Canonical	Palatal.	Deletion	Wrong
LF (1~50)	63.6	19.1	9.4	8.8
HF (>50)	64.2	23.8	9.2	7.4
Average	63.9	21.4	9.3	8.1
	$F(1,39)=.22$ $p>0.05$	$F(1,35)=18.3$ $P=.000$**	$F(1,37)=0.0$, $p>0.05$	$F(1,35)=0.54$ $p>0.05$

As shown in Table 3, a one-way ANOVA with the within-subjects factor Frequency was performed. Out of four variant types, frequency reached significance only within palatalization variant condition. That is, palatalization occurred more frequently in high-frequency words than in low-frequency words (23.8% vs. 19.1%). This definitely provides additional evidence for frequency-sensitive production for L2 speakers as consistent with previous findings for L1 speakers (Cooper and Paccia-Cooper 1980, Bush 2001).

In summary, the results indicate that Korean L2 speakers are sensitive to word frequency, giving rise to emergence of different variant patterns in palatalization environments. Furthermore, it can be interpreted to suggest that the likelihood of palatalization depends on word-frequency even for L2 speakers like L1 speakers. This finding contributes to L2 production study in that our results provide additional support for the notion that frequency information may be encoded in the word representation for L2 speakers' mental lexicon.

2.4.2 Word-final consonant type and palatalization

As aforementioned, since there have been rare studies on the effect of underlying word-final alveolars on the pronunciation variant patterns in the palatalizable context, the current study contributes to revealing such a feature for L2 speakers' production.

Table 4 clearly shows the mean rates of each possible variant realization (canonical, palatalization, deletion, and wrong form) by the underlying word-final alveolars (/t, d, s, z/). First, production patterns significantly varied by underlying word-final alveolars (X^2(df9)=1103, $p<0.001$). Moreover, canonical variants were found most regardless of word-final segments (77.4%), and then palatalization was frequent (14.7%), while deletion and wrong pronunciation were comparatively rare (respectively 5.8% and 1.9%). Finally, palatalization was realized most for the underlyingly /s/-final words (17.9%), then for /t/-final words (17.1%), and then for /d/- or /z/-final words (13% or 10.7%). Post-hoc pairwise comparison analysis (LSD) exhibited that there were significant differences between /s/ and /t/ conditions ($p<0.05$), and between /t/ and /z/

or /d/ conditions ($p<0.05$). However, the consonant effect did not reach significance between /z/ and /d/ conditions ($p>0.05$). These results indicate that word-final consonant type affected the degree of palatalization for Korean L2 speakers and palatalization were more frequent when the underlying segments were voiceless than voiced alveolars (e.g., *kiss you* >> *meet you* >> *as you, send you*).

Table 4. Rates of each production variant by underlying word-final segments

Underlying word-final segments	Production types (%)			
	Canonical	Palatal.	Deletion	Wrong
/t/	77.8	17.1	3.1	1.8
/d/	72.6	13	10.9	2.8
/s/	77	17.9	3.4	1.5
/z/	82	10.7	5.7	1.3
	$F(3,39)=16.3$	$F(3,81)=7.73$	$F(1,36)=5.67$,	$F(3,39)=1.16$
	$P<0.001$**	$P=.000$**	$P=0.003$**	$p>0.05$

Such rather an unexpected trend might be attributable to preference for less marked voiceless /ʃ, tʃ/ to more marked voiced palatoalveolars /ʒ, dʒ/, which will be discussed later. As demonstrated in the Table 4 above, in addition to palatalization variants, the occurrences of canonical and deletion variants were also affected by word-final segments in palatalizable contexts.

A two-way (word-final consonant type × production) repeated-measures ANOVA was run. Analyses exhibited no significant main effect of word-final consonant type ($F(3,21)=0.08$, $p>0.05$) but production type approached significance ($F(3,21)=54.9$, $p=0.000$). However, there was no interaction as illustrated in Figure 2 ($F(9,63)=1.6$, $p>0.05$).

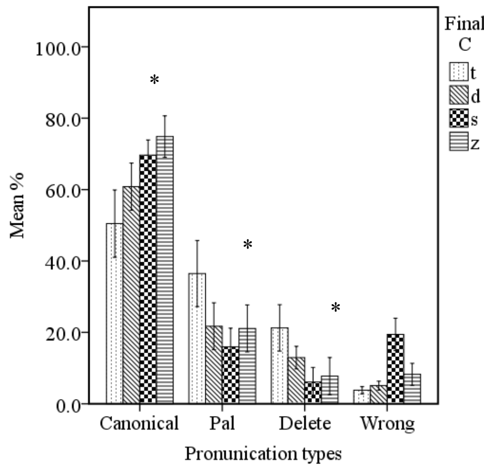

Figure 2. Mean rates of four variants by the underlying word-final segments (/t, d, s, z/). Dotted bars for /t/; dashed bars for /d/; checkered bars for /s/; parallel bars for /z/ (* represents a significant difference: p<0.05).

Of interest here is the indication that word-final targets as well as lexical frequency can be taken into consideration when Korean L2 speakers recognize English words in a palatalizable environment. Moreover, higher rates of canonical variants indicate that Korean L2 speakers do not palatalize overall. Furthermore, it was found that their overall production patterns as well as the likelihood of palatalization were influenced by word-final segments.

2.4.3 Number of syllables and palatalization

Another interesting factor explored in the present study is the number of syllables of target words on the production patterns and especially, the likelihood of palatalization. Table 5 shows the mean rates of each possible pronunciation variant by the number of syllables of the target words. First, as demonstrated by chi-square test, the production patterns significantly differed by the number of syllables (X^2(df9)=1103, $p<0.001$). Second, the occurrences of each variant as well were determined by the number of syllables. The occurrences of canonical variants were affected by the number of syllables, showing that trisyllabic words were less likely to undergo palatalization but tended to preserve the underlying form the most (83.3%), then disyllabic words (76.7%), and then monosyllabic words the least (72.7%). Furthermore, palatalization variants were found most for monosyllabic words (e.g., *beat, meet*, etc. 20%), then for disyllabic words (12%), and then for trisyllabic words (7.1%). The effect of the number of syllables on the likelihood of palatalization approached marginal significance ($F(2,44)=2.9$, $p=0.06$). Post-hoc pairwise comparisons (LSD) showed that there were significant differences between monosyllabic and di- or tri-syllabic words ($p<0.05$), while there was no significant difference between di- and tri-syllabic words ($p>0.05$). These results suggest that the less syllables words have, the more likely they are to palatalize for Korean L2 speakers.

Table 5. Rates of each production variant by number of syllables of the target words

No. of syllables	Production types (%)			
	Canonical	Palatal.	Deletion	Wrong
Mono- (e.g., *beat*)	72.7	20	5.7	2.1
Di- (e.g., *input*)	76.7	12	7.1	4
Tri- (e.g., *interrupt*)	83.3	7.1	4.7	2.3
	F(2,74)=8.41 P=0.001**	F(2,44)=2.9 P=0.06	F(2,42)=4.26, P=0.02*	F(2,38)=3.0 P=0.05

Finally, in order to see the effect of the number of syllables on the rates of pronunciation variants by production type, a two way repeated-measures ANOVA was performed. Analyses revealed that there were a highly significant main effect of production type ($F(3,39)=98$, $p<0.001$), and their interaction reached significance ($F(6,78)=4.13$, $p=0.001$). Their interaction is due to the observation that the occurrences of canonical variants and deletion forms differed by number of syllables. However, there was no significant main effect of the number of syllables ($F(2,26)=1.07$, $p>0.05$). These results also corroborate the fact that Korean speakers' production patterns differed by the number of syllables of the target words in palatalizable contexts.

2.4.4 Number of word-final consonants and palatalization

To see the number of word-final consonants on the production patterns and the degree of occurrences of palatalization, rates of each possible variant were measured. Results showed that although production patterns significantly differed by the number of codas of the target word finals syllables (X^2(df6)=522, $p<0.001$), the likelihood of palatalization did not differ by the number of final codas as illustrated in Table 6. However, the occurrences of canonical variants were determined by the number of final codas. Specifically, the underlying word-final alveolars remained constant as part of single or double codas more frequently than as part of triple codas (71.2% vs. 69.3% vs. 58.1%). Furthermore, the number of final codas also influenced the different rates of wrong pronunciation variants. This finding indicates that the overall production patterns are affected by the number of final codas, but not the degree of palatalization for Korean L2 speakers.

Table 6. Rates of each production variant by number of coda consonants of the target words

No. of consonants	Production types (%)			
	Canonical	Palatal.	Deletion	Wrong
Singleton (e.g., *hit*)	71.2	17.3	4.5	1.7
Double (e.g., *act*)	69.3	16.5	9.2	4.5
Triple (e.g., *involves*)	58.1	24	10	9.2
	F(2,78)=9.71	F(2,56)=.92	F(2,36)=2.56	F(2,54)=21.1
	P=0.000**	P>0.05	P=0.09	P=0.000**

The results of a two-way repeated-measures ANOVA showed that there was a significant main effect of production type (F(3,51)=73.11, p<0.001, but no main effect of number of final codas (F(2,34)=1.55, p>0.05). Interaction, however, reached significance, confirming the chi-square test result and showing that the number of codas affects the overall variant patterns (F(6,102)=4.42, p=0.001). This interaction effect is attributable to the fining that the occurrences of canonical variants and wrong pronunciation forms were different by the number of codas. That is, canonical variant was most favored for singleton codas, and wrong pronunciation was elicited mostly for triple codas.

2.4.5 Effect of wordhood on palatalization

Another interesting potential factor was investigated, i.e., wordhood to see if it influences the production patterns in palatalizable contexts as well as the likelihood of palatalization. As illustrated in Figure 3, canonical variants were favored for real words (e.g., *rea[d] you*) than for nonce words (e.g., *nood you*, 48.1% vs. 28%, F(1,37)=36, p<0.001). However, of interest was that palatalization variants were found more frequently for nonce words than for real words (41% vs. 33.8%, F(1,21)=7.9, p=0.1). This might be attributable to the fact that the number of tokens of nonce words was substantially smaller than that of real words (10 tokens vs. 192 tokens). Additionally, deletion variants were more common for nonce words than for real words (21% vs. 7.4%, F(1,20)=30.23, p<0.001). A 2-way (wordhood × production type, 2 x 3) repeated-measures ANOVA revealed that there was no main effect of wordhood (F(1,9)=0.01, p>0.05), but a significant main effect of production type (F(2,18)=7.39, p=0.005). Interaction reached significance as demonstrated in Figure 3 (F(2,18)=6.26, p=0.009).

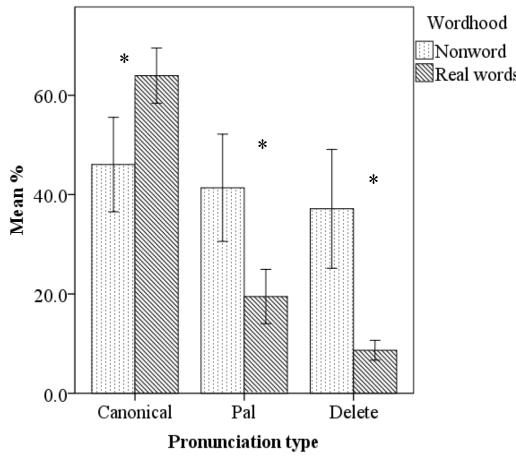

Figure 3. Mean rates of four variants by wordhood. Dotted bars for nonce words; dashed bars for real words. (* represents a significant difference: p<0.05).

Since real words end with four types of alveolars (/t, d, s, z/), while nonce words end with only /t, d/, both real words and nonce velars ending only with final /t, d/ were compared and analyzed to examine the potential effect of wordhood on the degree of palatalization. Table 7 shows the rates of the occurrences of palatalization for real and nonce words with final /t/ and /d/. Palatalization occurred more frequently in nonce words than in real words whether the final alveolars were /t/ or /d/.

Table 7. Rates of palatalization variants by word-final segments and wordhood

Wordhood	Word-final target (%)	
	/t/	/d/.
Real words (e.g., *hit*)	32	28
Nonce words (e.g., p*wet*)	42	100
	F(1,23)=796,p=0.01*	F(1,23)=3379, p<0.001**

A 2-way ANOVA with final segment (/t/ vs. /d/) and wordhood as within-subjects factors revealed that there were a main effect of wordhood ($F(1,23)=350$, $p<0.001$), a main effect of final segment ($F(1,23)=165$, $p<0.001$), and their interaction approached significance ($F(1,23)=278$, $p<0.001$). These results indicate that wordhood affected the likelihood of palatalization for Korean L2 speakers.

2.4.6 Effect of preceding vowels on palatalization

Since few studies attempted to uncover the effect of vowels preceding the final alveolars on the applicability of palatalization, we explored the possibility that the quality of preceding vowels can influence the occurrences of palatalization. As illustrated in Figure 4(a), there was a main effect of twelve vowel types (F(12, 373)=1.8, p=0.04). This result suggests that the likelihood of palatalization was affected by the quality of preceding vowels. To see what type of vowel quality is involved, we examined the effect of vowel backness, vowel height, and vowel tenseness. As shown in Figure 4(b), a one-way repeated-measures ANOVA exhibited that only vowel backness exerted a significant influence on the realization of palatalization (F(1,39)=11.3, p=0.002). Specifically, palatalization variants were favored more greatly when the preceding vowels were front than when they were back (29% vs. 23%).

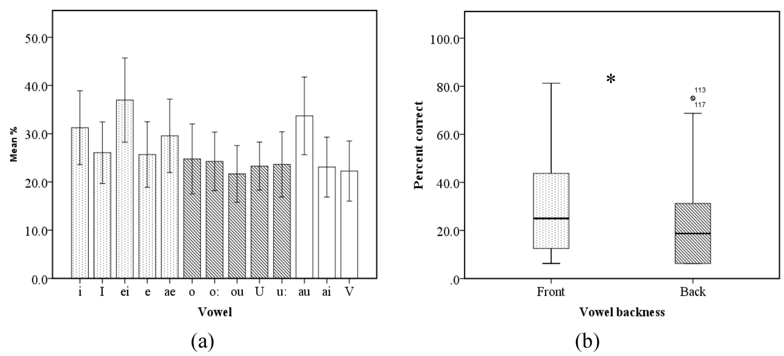

Figure 4. Mean rates of palatalization variants by vowels. Dotted bars for front vowel condition; dashed bars for back vowels (* represents a significant difference: p<0.05).

However, the likelihood of palatalization did not differ either by vowel height (high, mid, low, F(2,308)=0.54, p>0.05) or by vowel tenseness (F(1,385)=1.5, p>0.05). In sum, our phonetic analysis demonstrates that palatalization variant realization varied by the backness of vowels preceding final alveolars for Korean L2 speakers. This result is revealing in that preceding vowels might contribute to some extent to the realization of palatalization, facilitating the assimilation of word final alveolar targets. This will be discussed more in the next section.

3. Discussion

3.1 What types of variation forms emerge for Korean L2 speakers' palatalization in English?

Our production experiment showed that word-final alveolars were realized primarily in four types in palatalizable context: canonical variants, palatalization, deletion, and wrong pronunciation. Canonical realization was found most (63.9%) and palatalization occurred second most frequently (21.4%). On the other hand, deletion and wrong pronunciation were comparatively rare, respectively 9.3% and 8.1%. This variation pattern differed by word frequency, word-final alveolar types, number of syllables of the target words, number of word-final codas, and wordhood. The highest rate of the canonical variants could lead us to speculate that since Korean does not have word-boundary palatalization like English, but allows only morpheme boundary counterpart, Korean L2 learners might have failed to palatalize word-final alveolars across word boundaries. Alternatively, they could not have been exposed to palatalized exemplars uttered by native speakers of English. Comparatively lower rates of occurrence of the deletion variants might be due to the fact that since target words with final double or triple codas constituted more than half of the entire stimuli used in the present study (101 out of 192 tokens), Korean speakers might have had trouble producing complex codas and adopted a deletion strategy due to an influence of (or to adapt to) their L1 Korean syllable structure, i.e., CVC. Or a large portion of the final /d/, /s/, or /z/ represents past tense marker, their person singular or plural markers, and thus speakers might have suffered from processing additional morpheme and attention load, giving rise to deletion or wrong pronunciation forms. These results indicate that like native speakers of English, L2 speakers' production as well reflect a range of pronunciation variation.

Another implication is that such wide phonological variation requires even L2 listeners to take into consideration many variables such as lexical frequency, morphological environments, and phonological environments in order to successfully recover speakers' intended words (Dilley and Pitt 2007, Gaskell and Marslen-Wilson 1998). Furthermore, our results provide additional interesting implications about Korean L2 speakers' production of optional English word-boundary palatalization.

First, Korean L2 speakers' production variability in palatalization could be interpreted to mean that they might have been exposed to variation used in spoken corpus data during formal education or informal spontaneous conversation. This explanation is evidenced by lexical frequency, which seems to be responsible for the different likelihood of palatalization. As previously reported, the percentages of the occurrences of canonical variants, deletion forms, and wrong pronunciation did not differ according to word frequency. However, interestingly, higher frequency words tended to exhibit the higher likelihood of palatalization than lower frequency words (23.8% vs. 19.1%) as is consistent with previous results found for native speakers of English (Cooper and Paccia-Cooper 1980, Bush 2001). We could offer many possible explanations for such a word frequency effect for L2 speakers. For one thing, word frequency information might have been encoded in word representation in Korean L2 speakers' mental lexicon, depending on the amount of exposure to English or the different proficiency of English as is suggested by Jescheniak and Levelt (1994) and Miozzo and Caramazza (2003). Coupled with the association of frequency with words, frequency-sensitive constraints might have worked, giving rise to the different likelihood of palatalization. It is not a novel idea that frequency-sensitive constraints handle frequency-conditioned phonological variation (Hammond 2004, Coetzee 2008, Hong 2009).[5] Following Hammond's (2004) proposal, we employ a frequency-sensitive markedness constraint Pal (HF) and a relevant ranking as seen in (1) and (2). An optimality-theoretic way can provide a formal account for frequency effects on phonological variation by incorporating frequency-sensitive constraints and allowing them to interact with phonological constraints.

(1) a. PAL(HF)	Palatalize the final alveolars after a palatal glide in high-frequency words.
b. PAL	Palatalize the word-final alveolars after a palatal glide.
c. IDENT(ant, strid)	The feature values of [anterior] and [strident] in the input must be identical to those in the output.

(2) PAL (HF) >> IDENT (ant, strid) >> Pal

Let us examine the variability of palatalization according to word frequency with examples of "meet you" and "admit you". As illustrated in tableaux (3), the two-word sequences containing higher frequency words like "meet" undergo palatalization because the frequency sensitive markedness constraint PAL(HF) triggers it at the expense of violating IDENT(ant, strid). On the other hand, in cases like the string containing low-frequency words like "admit", PAL(HF) is vacuously satisfied and the word-final alveolar is not palatalized, remaining identical to the underlying segment.

(3) Asymmetry in the applicability of palatalization

/meet you/$_{HF}$	PAL(HF)	IDENT(ant, strid)	PAL
a. mit ju	*!		*
☞ b. mitʃə		**	

/admit you/	PAL(HF)	IDENT(ant, strid)	PAL
☞ a. ədmɪt ju			*
b. ədmɪtʃə		*!*	

[5] Hong (2009) accounts for frequency-conditioned optional flapping in American English by using frequency-associated identity constraints, following the same vein of Coetzee (2008), whereas Hammond (2004) resorts to high-frequency specified markedness constraints rather than frequency specified faithfulness constraints. See Hammond (2004) for the issue, i.e., whether it is appropriate to use frequency-associated markedness or faithfulness constraints. In the current study, we refer to frequency-sensitive markedness constraints rather than identity constraints, following Hammond's (2004) rationale.

The present study makes contribution to L2 production research in confirming that word frequency is an important parameter of organization of L2 speakers' as well as L1 speakers' mental lexicon and that it affects or interact with the likelihood of phonological rules.

Second, another possible explanation comes from an exemplar-based model. It was suggested that as two–word string phrases are used more frequently, they are likely to become more formulaic like monomorphemic words (Booij 1995, Ernestus 2000). Given that, higher frequency phrases have weaker word boundaries and so lead to more likelihood of palatalization than lower frequency strings with stronger word boundaries. This account, of course, assumes that palatalizaation basically is more like a word-internal process as proposed by Bush (2001). As is well-known, Korean palatalization occurs primarily across morpheme boundary within derived or complex words. For this reason, transferring their knowledge of L1 palatalization, Korean L2 speakers might have interpreted two-word sequences as a formulaic expression with a weaker word boundary and then processed L2 palatalization on the basis of a larger number of exemplars stored in their mental lexicon. In the similar vein, a more phonetically grounded account can be given. That is, as suggested by Bybee and Hopper (2001), as Korean speakers hear and utter higher frequency words or phrases more and more, these exemplars are highly likely to be produced with less articulatory efforts due to repetition and easier motor control than lower frequency exemplars. Such less articulatory efforts in production are usually accompanied by more gestural overlap between alveolars and a palatal glide, elevating the likelihood of coalescence or fusion like palatalization.

3.2 Do phonological environments affect Korean speakers' production of palatalization in English?

One of the important contributions made in the present study is that we revealed numerous effects of phonological environments on the likelihood of palatalization, which seems not to have been reported for native speakers of English. First, as mentioned earlier, word-final alveolar type affected the likelihood of palatalization. It was shown that palatalized variants were found most for final /s/ words (17.9%), then for final /t/ words (17.1%), and then final /z/ and /d/ words. That is, words with final voiced alveolars (/d, z/) showed a lower percentage of palatalization tokens (respectively, 13% and 10%). Additionally, voiced word-final /d, z/ were deleted more readily than voiceless ones (8.3% vs. 3.2%). A potential reason for lower rates of palatalization and higher rates of deletion for word-final segments /d, z/ might lie in that speakers have relatively more difficulty of preserving voiced palatoalveolars (/ʒ, dʒ/) due to the higher supralaryngeal oral pressure to maintain voicing than their voiceless counterparts (/ʃ, tʃ/). Thus, it seems that phonetically or phonologically marked resulting sounds tend to be avoided or deleted in the palatalizable contexts.

Next, we found that the number of syllables of target words also affected the applicability of palatalization. Specifically, word-final alveolars were realized as palatalized in monosyllable words more frequently than in di- or tri-syllable words (20% vs. 12% vs. 7.1%). It might be the case that number of syllables is related to frequency of words used in the present study. In fact, monosyllable words constitute 85% of high-frequency words (85 out of 96 tokens), and disyllabic words make up the rest of 15%. On the other hand, di- or tri-syllabic words constitute 36% of the low frequency tokens. Since a larger portion of monosyllabic words correspond to high-frequency stimuli in the current study, palatalizaltion seems to have been found more for shorter words than for longer words.

Another interesting factor we found was vowel quality on palatalization. The preponderance of palatalization for a sequence of front vowels and an alveolar over for words with back vowels is intriguing (29% vs. 23%). It seems that front vowels before an alveolar might have facilitated palatalization more greatly than back vowels. That is, front vowels preceding an alveolar appear to be another trigger for palatalization along with the real trigger, i.e., a palatal glide since front vowels share a palatal region in the oral cavity as place of articulation with a palatal glide [j]. Note that there are many languages with palatalization whereby alveolars become palatalize after front vowels and [j] rather than before the same trigger segments (Baztan et al. from Basque dialects, Hualde 1991).

Finally, we found that the number of word-final codas did not influence the degree of palatalization. That is, the likelihood of palatalization did not significantly differ regardless of whether the word-final alveolar belongs to singleton, double, or triple codas. However, canonical realizations were predominant for singleton codas over for double or triple codas (respectively, 71% vs. 69% vs. 58%). Considering the rates of other types of variants, word-final alveolars were realized as deletion and wrong pronunciation variants when they were part of double or triple codas than singleton codas as seen in Table 6 in previous section. This leads us to speculate that it might have been easier to retain the underlying alveolars for singleton codas and to palatalize, or delete the final alveolars which are part of complex codas probably to avoid marked coda patterns.

In summary, our study makes a significant contribution to L2 speakers' production research in that it has revealed and draws a comprehensive picture on the lexical factor and phonological effects on their production of a phonological rule like palatalization.

4. Conclusion

The current research shows that L2 speakers as well as L1 speakers exhibit variation in producing categorical phonological rules in target languages: canonical variants, palatalization, deletion and wrong pronunciation.

Furthermore, it confirms that palatalization is one of several types of variants which occur in assimilable contexts. Moreover, our study indicates that word frequency plays a crucial role in the likelihood of palatalization for Korean L2 speakers as is consistent with L1 speakers. Finally, it shows that Korean L2 speakers' realization of palatalization in English is affected by many phonological factors such as word-final alveolar type, number of syllables of target words, preceding vowel type, etc.

However, more comprehensive data for native speakers of English is needed to compare with the results obtained in the current study. Additionally, ample data still needs to be collected for other L2 speakers with different L1 background in order to verify effects of word frequency and phonological environments and to establish universal factors which can be seen potentially in general L2 production. Furthermore, it is worth investigating whether lexical and phonological factors found in the current study shows variation in the weight of each factor depending on the L2 speakers' proficiency of target languages.

APPENDIX (Stimuli)

Sample low-frequency words

V	t	d	z	s
i	beat (45)	leaned (23)	sees (35)	treats (4)
ɪ	print (10)	bid (8)	pins (0)	dismiss (8)
ɛ	rent (7)	pretend (12)	fed (22)	access (9)
æ	bat (13)	hand (9)	plans (20)	attacks (3)
u	shoot (15)	excused (3)	excuse (14)	shoots (2)
ʊ	suit (20)	exclude (23)	proves (8)	books (0)
aʊ	mount (60	bound (19)	houses (4)	mouse (10)
o	boast (3)	posed (13)	borrows (1)	notes (9)
ɔ	exhaust (2)	reward (3)	draws (11)	opts (1)
ɑ	opt (7)	reckoned (10)	responds (4)	pops (1)
ʌ	interrupt (5)	nudged (0)	lulls (0)	adjusts (1)
aɪ	fight (40)	modified (12)	occupies (4)	likes (21)

Sample high-frequency words

V	t	d	z	s
i	meet (141)	need (356)	needs (97)	cheers(14470)
ɪ	hit (88)	did (1044)	gives (104)	miss(92)
ɛ	get (2210)	send (80)	sells (76)	access (100)
æ	act (59)	stand (326)	as (3006)	pass (58)
u	fruit (52)	moved (146)	choose (68)	news(145)
ʊ	put (900)	should (11120)	lose (277)	books (131)

o	boat (74)	told (372)	knows (84)	costs (120)
ɑ	caught (86)	nod (60)	dogs (78)	cross(70)
ɔ	support (97)	caused (96)	thongs(17129)	wants (89)
ʌ	cut (145)	loved (150)	becomes (77)	discuss (56)
aɪ	site (155)	replied (56)	advise (54)	nice (134)
e	wait (84)	made (943)	sales (104)	cases (431)

(token frequencies listed in Leech et al. (2001) based on BNC are given in parentheses).

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