Journal of Pan-Pacific Association of Applied Linguistics, 25(2), 1-19.
https://doi.org/10.25256/PAAL.25.2.1

Korean Learners' Production of English Consonant Clusters with an Onset Liquid*

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Seo, M. (2021). Korean learners' production of English consonant clusters with an onset liquid. ***Journal of Pan-Pacific Association of Applied Linguistics, 25*****(2), 1-19.**

This study examined Korean learners' production of intervocalic English biconsonantal clusters consisting of /p/, /t/, /k/, /m/, /n/, or /ŋ/ followed by /l/ or /ɹ/. The results of the production experiment showed several factors influencing Korean learners' production. First, Korean learners' production was influenced by their L1 sound inventory. The mispronunciation of a liquid (i.e., /l/ as [ɹ] and /ɹ/ as [l]) was observed and this will be due to the fact that [l] and [ɹ] are not contrastive in Korean. Second, L1 phonological rules affecting a post-consonantal onset liquid influenced Korean learners' production of English consonant clusters containing a liquid. The cluster /tl/ was mostly pronounced as [ll] and /nl/ as [ll] or [nn]. In addition, the nasalization of a stop consonant before a liquid was attested. Next, Korean learners' production also exhibited the influence of phonetic similarity between the two members of a cluster by illustrating relatively lower production accuracy for /tl/, /tɹ/, and /nl/ consisting of two alveolar consonants. Finally, familiarity with the test words seemed to be a factor influencing Korean learners' production. Korean learners illustrated relatively lower production accuracy for the words *outlet* and *online* which are frequently used as loanwords in Korea.

Keywords: L2 production, L1 phonology, liquid, English consonantal clusters

1 Introduction

According to a number of previous studies, second language (L2) sound production is influenced by various aspects of learners' first language (L1) phonology. First of all, L2 learners have difficulty pronouncing the sounds which do not belong to their L1 sound inventory. (Eckman et al., 2003; Lado, 1957; Stockwell & Bowen, 1965; Stockwell et al., 1965). For example, according to Seo and Lim (2009), Korean learners of English showed difficulty

* This paper has been supported by the 2020 sabbatical year research grant of Hannam University.

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correctly pronouncing English /z/ and /ʒ/ which do not belong to Korean consonant inventory.

Next, the similarity or difference of contrastive sounds between L1 and L2 plays an important role in L2 production. Thus, L2 sounds contrastive in L1 are easier to produce while those not contrastive in L2 are harder to produce correctly. In Korean, unlike English, [l] and [ɹ] are not contrastive sounds. Instead, [l] and [ɹ] are allophones of the same phoneme /L/ which is realized as [l] or [ɹ] (or [ɾ]) depending on the syllable position (Cho, 1997; Kang, 2003; Lee, 2001; Seo, 2004). Therefore, it has been shown in numerous studies that Korean learners of English have difficulty in correctly producing English [l] and [ɹ] (Aoyama et al., 2004; Best & Strange, 1992; Borden et al., 1983; McClelland et al., 1999).

In addition, the wrong application of an L1 phonological rule to an L2 sound can result in incorrect L2 sound production. In Korean, there is a phonological rule changing a stop into a nasal before a nasal, as can be seen from /pap + muL/ → [pammul] 'ricewater', /tot + namuL/ → [tonnamul] 'sedum', and /hak-mun/ → [haŋmun] 'learning' (Seo et al., 2005; Shin & Cha, 2004; Sohn, 1999). By the production experiment with Korean learners of English, Seo et al. (2005) showed that the modification of a stop into a nasal before a nasal was observed in Korean learners' production of English 'stop + nasal' sequences, for example, pronouncing 'bookmark' as [buŋmaɹk].

In the present study, the influence of Korean phonological rules on L2 speech production will be investigated. In particular, an English intervocalic biconsonantal cluster containing the liquid /l/ or /ɹ/ as its second member will be the target of the present study since a post-consonantal onset liquid in Korean can be realized as [n] nasalizing its previous consonant or as [l] changing its preceding consonant into [l]. Thus, the influence of L1 phonological rules on L2 production will be studied by investigating how Korean learners of English produce English biconsonantal clusters containing the liquid /l/ or /ɹ/ in onset position.

2 Literature Review

In Korean, an underlying post-consonantal liquid /L/ in onset position is realized as [n] or [l] depending on the place of articulation of its preceding consonant.

(1) Realization of post-consonantal /L/ in onset position
(Iverson & Kim, 1987; Iverson & Sohn, 1994; Lee, 2001)

a. after a non-coronal consonant

/pəp-Ljul/	[pəmnjul]	'law'

/pok-Lak-wən/	[poŋnagwən]	‘Paradise Recovered’
/sam-Lju/	[samnju]	‘third-rate’
/jəŋ-Lak/	[jəŋnak]	‘downfall’

b. after a coronal consonant

/tikɨt + LiɨL/	[tigɨlliɨl]	'the letters ‘ㄷ’ and ‘ㄹ''
/tɕin-Li/	[tɕilli]	'truth'
/sən-Lɨŋ/	[sənnɨŋ] or [səllɨŋ]	proper name

Note: ‘-’ morpheme boundary, ‘+’ word boundary

As can be seen from the first two examples in (1a), an underlying onset /L/ is realized as [n] when a non-coronal stop /p/ or /k/ precedes. In addition, a non-coronal stop is changed into a nasal. Thus, in Korean, there are phonological rules modifying /pL/ and /kL/ into [mn] and [ŋn] respectively. In case an onset /L/ is preceded by a non-coronal nasal /m/ or /ŋ/, it is also realized as [n] as illustrated in the last two examples in (1b). Thus, /mL/ and /ŋL/ are realized as [mn] and [ŋn] respectively. After a non-coronal stop /t/, an onset /L/ is realized as [l], changing /t/ into [l] as shown in (1b). That is, /tL/ is realized as [ll]. In addition, /nL/ surfaces as [ll] or [nn] in Korean.

With the interference of such L1 phonological rules, it is expected that Korean learners of English will have trouble correctly pronouncing English intervocalic biconsonantal clusters with a liquid in onset position such as /pl/, /pɹ/, /tl/, /tɹ/, /kl/, /kɹ/, /ml/, /mɹ/, /nl/, /nɹ/, /ŋl/, and /ŋɹ/. If only the interference of L1 phonological rules is taken into account, it is expected that all those English clusters will be equally difficult to Korean learners of English.

Following Kawasaki (1982) and Ohala (1992, 1993), Seo (2003) argued that sound alternations in a consonant cluster are motivated by contrasts of weak perceptibility which are triggered by phonetic similarity between the two members of a cluster. Based on this, for a consonant cluster in which at least one consonant is a sonorant, Seo (2003) hypothesized that a homorganic cluster will be more likely to be modified than a heterorganic cluster and showed that this is actually the general pattern found in languages. With this account considering the similarity of the two consonants in a cluster, it is expected that English clusters consisting of two alveolar consonants such as /tl/, /tɹ/, /nl/, and /nɹ/ will be more difficult to pronounce for Korean learners of English than English clusters consisting of a non-coronal stop /p/ or /k/ plus a liquid. In addition, /nl/ and /nɹ/ are expected to give the most difficulty to Korean learners since the two members of the clusters are both sonorants and alveolars.

This study aims to investigate the influence of Korean phonological rules and that of the similarity account through Korean learners’ production

patterns for intervocalic English clusters consisting of /p/, /t/, /k/, /m/, /n/, or /ŋ/ followed by /l/ or /ɹ/. For this, it will be examined how Korean learners' production of the English clusters are different according to the manner/place of articulation of the first consonant in the cluster. By comparing Korean learners' production patterns of the English clusters to native English speakers', the influence of the Korean phonological rules will be also examined. In addition, it will be investigated how Korean learners' production of the English clusters is different according to a liquid type involved.

In summary, the research questions to be examined in this study are as follows:

1) What are Korean learners' production patterns for English 'consonant + liquid' clusters? How are they different from native English speakers'?
2) Is Korean learners' production of an English 'consonant + liquid' cluster different according to a liquid type involved?
3) Is Korean learners' production of an English 'consonant + liquid' cluster different according to the manner/place of articulation of the first consonant in the cluster?

3 Research Methodology

3.1 Participants

The production experiment was performed by 10 (5 males, 5 females) Korean learners of English. They had TOEIC scores of 500s or below and all of them were university students in Daejeon. For base-line data of native English speakers, four native speakers of English (2 males, 2 females) conducted the production experiment. They were all from Canada and lived in Korea for 6.3 years on average at the time of recording.

3.2 Stimuli

For the production experiment, 36 words with a word-medial biconsonantal cluster consisting of /p/, /t/, /k/, /m/, /n/, or /ŋ/ followed by /l/ or /ɹ/ were employed. Table 1 below illustrates a full list of the words used in the experiment.

Table 1. Words for the Production Experiment

Cluster Type	Words
/pl/	shipload, shoplift, topline
/pɹ/	lipread, sliproad, upright

/tl/	hotline, streetlamp, outlet
/tɹ/	hatrack, hitrun, footrace
/kl/	blacklist, booklover, picklock
/kɹ/	bookrest, stockroom, cookroom
/ml/	slimline, homeland, gumlike
/mɹ/	homerun, primrose, steamroller
/nl/	mainland, moonlight, online
/nɹ/	sunrise, moonrock, onrush
/ŋl/	gangland, kinglike, longlived
/ŋɹ/	songwriter, strongroom, longreach

3.3 Procedure and analysis

In order to induce natural speech, each word in Table 1 was put in a carrier sentence "please say _____". A list of sentences with target words were presented to each participant in a randomized order and each participant was asked to read the presented sentences as naturally as possible. For the recordings which were made in a quiet room, a head-mounted microphone (Audio-Technica M8531) and a TASCAM HD-P2 recorder were used. The digitization setting was 44,100 Hz sampling rate and 16 bit quantization. By the production experiment, 360 tokens (36 words × 10 speakers) were obtained from the Korean participants and 144 tokens (36 words × 4 speakers) from the native English participants.

The segmental realizations of the biconsonantal clusters under consideration were examined by looking at the spectrograms using the *Praat* program and also by listening to each of the recordings. In identifying segmental realizations from the spectrograms, acoustic correlates of each consonant type in Ladefoged and Johnson (2015) were employed.

Table 2. Acoustic Correlates of Consonants (Ladefoged & Johnson, 2015, p. 214)

Consonants	Acoustic Correlates
Stop	Gap in pattern, followed by burst of noise for voiceless stops
Nasal	Formant structure similar to that of vowels but with nasal formants at about 250, 2500, and 3250 Hz
Retroflex	General lowering of the third and fourth formants
Lateral	Formant structure similar to that of vowels but with formants in the neighborhood of 250, 1200, and 2400 Hz

Figure 1 below shows a spectrogram of the word *upright* produced by a native English speaker. In the spectrogram, the part with gap followed by burst of noise confirms [p] and the part with the lowered third formant [ɹ].

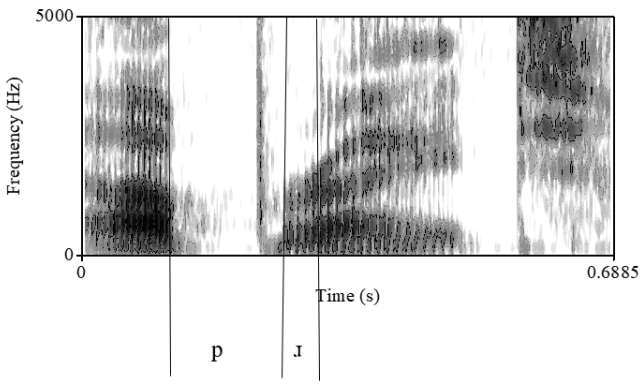


Figure 1. A spectrogram of *upright* by a native English speaker

A spectrogram of the word *upright* produced by a Korean speaker is shown in Figure 2 below. In the spectrogram, it can be seen that the Korean speaker pronounced /p/ as [m] by the formant structure which is a clear mark of a nasal consonant. In addition, the lowered third formant as in the native English speaker's spectrogram in Figure 1 shows that /ɹ/ was correctly pronounced as [ɹ] by the Korean speaker.

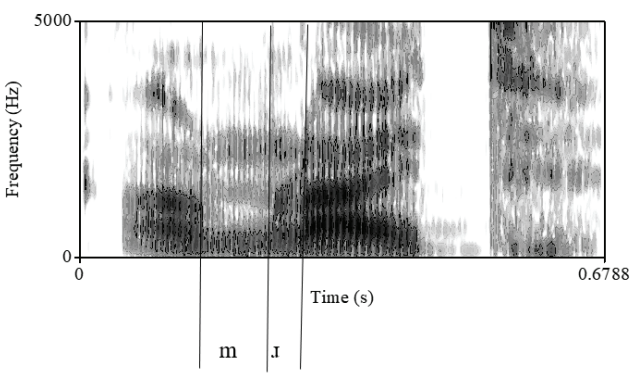


Figure 2. A spectrogram of *upright* by a Korean speaker

Figure 3 below shows a spectrogram of the word *upright* produced by another Korean speaker. Formants during the articulation of /p/ show that the Korean speaker pronounced /p/ as a nasal consonant and no lowering of the third formant during /ɹ/ shows that it is incorrectly pronounced as [l].

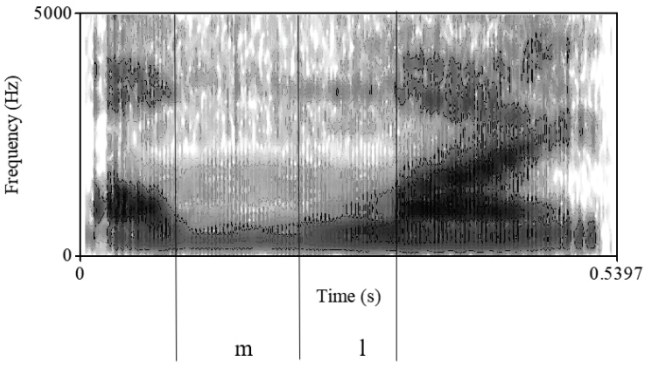


Figure 3. A spectrogram of *upright* by a Korean speaker

4 Results

Korean learners' production patterns for each of the English biconsonantal clusters examined in this study will be presented first and then the results of the statistical analyses.

4.1 Production patterns

Table 3 below illustrates Korean learners' production patterns for the English clusters /pl/ and /pɹ/ observed in 60 tokens (30 tokens for each cluster type).

Table 3. Production Patterns for /pl/ and /pɹ/

Cluster	Production	Total
/pl/	**[pˀl]** 17 (56.7%), **[ml]** 10 (33.3%), **[pˀɹ]** 2 (6.7%), **[mɹ]** 1 (3.3%)	30 (100%)
/pɹ/	**[pˀɹ]** 15 (50.0%), **[mɹ]** 6 (20.0%), **[pˀl]** 4 (13.3%), **[ml]** 3 (10.0%), **[bl]** 1 (3.3%), **[p^hɹ]** 1 (3.3%)	30 (100%)

Native English speakers pronounced /pl/ and /pɹ/ as [pˀl] and [pˀɹ] respectively with the unreleased stop [pˀ] in all the tokens obtained from the production experiment. On the other hand, Korean learners produced them in various ways, as shown in Table 3. For /pl/, the native English speaker-like pronunciation (i.e., [pˀl]) was most frequently observed (17 tokens out of 30, 56.7%), followed by [ml] (10 tokens, 33.3%), [pˀɹ] (2 tokens, 6.7%), and [mɹ] (1 token, 3.3%). It can be said that Korean learners' pronunciation errors for /pl/ were caused by the nasalization of the stop /p/ and/or the mispronunciation of /l/ as [ɹ].

For /pɹ/, the most frequent pronunciation was [pˀɹ] (15 tokens, 50.0%), followed by [mɹ] (6 tokens, 20.0%), [pˀl] (4 tokens, 13.3%), [ml] (3 tokens, 10.0%), [bl] (1 token, 3.3%), and [p^hɹ] (1 token, 3.3%). In pronouncing the cluster /pɹ/, in addition to the nasalization of the stop /p/ and the mispronunciation of the liquid involved (i.e., /ɹ/ as [l]), the voicing of /p/ as [b] and the release of /p/ accompanying aspiration were also found. For /pl/ and /pɹ/, the pronunciation [mn] which is expected to occur considering the Korean phonology was not observed.

Table 4 below shows Korean learners' production patterns for the English clusters /tl/ and /tɹ/ observed in 60 tokens (30 tokens for each cluster type).

Table 4. Production Patterns for /tl/ and /tɹ/

Cluster	Production	Total
/tl/	**[ll]** 12 (40.0%), **[tˀl]** 10 (33.3%), **[tˀɹ]** 3 (10.0%), **[nl]** 2 (6.7%), **[t^hl]** 2 (6.7%), **[t^hɹ]** 1 (3.3%)	30 (100%)
/tɹ/	**[tˀɹ]** 11 (36.7%), **[tˀl]** 4 (13.3%), **[tʃɹ]** 3 (10.0%), **[nɹ]** 3 (10.0%), **[nn]** 2 (6.7%), **[dɹ]** 2 (6.7%), **[t^hɹ]** 2 (6.7%), **[ll]** 1 (3.3%), **[nl]** 1 (3.3%), **[ɹ]** 1 (3.3%)	30 (100%)

In all the tokens from the production experiment, native English speakers pronounced /tl/ and /tɹ/ as [tˀl] and [tˀɹ] respectively with the unrelease stop [tˀ]. As shown in Table 4, Korean learners' pronunciations for the clusters were diverse. In case of /tl/, [ll] (12 tokens out of 30, 40.0%) was the most frequent one followed by [tˀl] (10 tokens, 33.3%), [tˀɹ] (3 tokens, 10.0%), [nl] (2 tokens, 6.7%), [t^hl] (2 tokens, 6.7%), and [t^hɹ] (1 token, 3.3%). The pronunciation [ll] which can be explained to occur due to the Korean phonological rule of changing /tL/ into [ll] was more frequently observed than the native English speaker-like pronunciation [tˀl]. Other pronunciation errors for /tl/ occurred due to the nasalization of the stop /t/, the mispronunciation of /l/ as [ɹ], and/or the release and aspiration of /t/.

For /tɹ/, the most frequent pronunciation was the native English speaker-like pronunciation [tˀɹ] (11 tokens out of 30, 36.7%) followed by [tˀl] (4 tokens, 13.3%), [tʃɹ] (3 tokens, 10.0%), [nɹ] (3 tokens, 10.0%), [nn] (2 tokens, 6.7%), [dɹ] (2 tokens, 6.7%), [t^hɹ] (2 tokens, 6.7%), [ll] (1 token, 3.3%), [nl] (3.3%), and [ɹ] (1 token, 3.3%). In incorrect pronunciations, the affrication, nasalization, voicing, aspiration, or deletion of /t/ and the mispronunciation of /ɹ/ as [l] were found. In addition, [nn] and [ll] were found, which shows the Korean phonological rule was in play when pronouncing the English cluster /tɹ/. It is interesting that [nl] was a realization pattern for the English /tl/ and /tɹ/ although it is not the pronunciation allowed in Korean.

Korean learners' production patterns for the English clusters /kl/ and /kɹ/ are shown in Table 5 below.

Table 5. Production Patterns for /kl/ and /kɹ/

Cluster	Production	Total
/kl/	**[kˀl]** 18 (60.0%), **[ŋl]** 5 (16.7%), **[ŋn]** 4 (13.3%), **[kˀɹ]** 2 (6.7%), **[ŋɹ]** 1 (3.3%)	30 (100%)
/kɹ/	**[kˀɹ]** 18 (60.0%), **[ŋɹ]** 5 (16.7%), **[kˀl]** 4 (13.3%), **[ŋl]** 2 (6.7%), **[gɹ]** 1 (3.3%)	30 (100%)

Native English speakers pronounced /kl/ and /kɹ/ as [kˀl] and [kˀɹ] respectively in all the tokens from the production experiment. In case of Korean learners, for /kl/, [kˀl] (18 tokens out of 30, 60.0%) was the most frequent form followed by [ŋl] (5 tokens, 16.7%), [ŋn] (4 tokens, 13.3%), [kˀɹ] (2 tokens, 6.7%), and [ŋɹ] (1 token, 3.3%). Korean learners' pronunciation errors occurred by nasalizing the stop /k/ and/or by mispronouncing /l/ as [n] or [ɹ]. The pronunciation [ŋn] occurred in 7 (13.3%) out of the 30 tokens, and this will be the influence of the Korean phonological rule of realizing /kL/ and [ŋn].

In case of /kɹ/, the native-like pronunciation [kˀɹ] (18 tokens out of 30, 60.0%) was the most frequently observed one followed by [ŋɹ] (5 tokens, 16.7%), [kˀl] (4 tokens, 13.3%), [ŋl] (2 tokens, 6.7%), and [gɹ] (1 token, 3.3%). Although [ŋn] was not observed for /kɹ/, the nasalization of /k/ was found in 23.3% of the 30 tokens. Thus, it can be said that the Korean phonological rule was partially in play when Korean learners pronounced the cluster /kɹ/. The mispronunciation of /ɹ/ as [l] and the voicing of /k/ were also observed in Korean learners' pronunciation of /kɹ/.

For the English clusters /ml/ and /mɹ/, Korean learners showed production patterns illustrated in Table 6.

Table 6. Production Patterns for /ml/ and /mɹ/

Cluster	Production	Total
/ml/	**[ml]** 24 (80.0%), **[mɹ]** 5 (16.7%), **[mn]** 1 (3.3%)	30 (100%)
/mɹ/	**[mɹ]** 21 (70.0%), **[ml]** 9 (30.0%)	30 (100%)

In all the tokens containing /ml/ and /mɹ/, native English speakers' pronunciations were [ml] and [mɹ] respectively. In case of Korean learners, for /ml/, [ml] (24 tokens, 80.0%) was the most frequently observed one followed by [mɹ] (5 tokens, 16.7%) and [mn] (1 token, 3.3%). For /mɹ/, [mɹ] was observed in 21 tokens (70.0%) out of 30 and [ml] in 9 tokens (30.0%). Thus, for the English clusters /ml/ and /mɹ/, most pronunciation errors were caused by the mispronunciation of the liquid involved. The nasalization of the lateral after the nasal /m/ was attested in 1 token containing /ml/ while the nasalization of the liquid /ɹ/ was not observed for /mɹ/.

Table 7 below illustrates Korean learners' production patterns of the English clusters /nl/ and /nɹ/.

Table 7. Production Patterns for /nl/ and /nɹ/

Cluster	Production	Total
/nl/	**[nl]** 13 (43.3%), **[ll]** 13 (43.3%), **[nɹ]** 3 (10.0%), **[nn]** 1 (3.3%)	30 (100%)
/nɹ/	**[nɹ]** 25 (83.3%), **[ll]** 3 (10.0%), **[nl]** 2 (6.7%)	30 (100%)

In all the tokens with /nl/ and /nɹ/, native English speakers' pronunciations were [nl] and [nɹ] respectively. On the other hand, Korean learners pronounced /nl/ as [nl] in 13 tokens (43.3%) out of 30, as [ll] in 13 tokens (43.3%), as [nɹ] in 3 tokens (10.0%), and as [nn] in 1 token (3.3%). The native English speaker-like pronunciation [nl] was observed in less than 50% of the tokens containing /nl/. Korean learners' pronunciation errors mostly occurred due to the Korean phonological rule realizing /nL/ as [ll] or [nn] (in 14 tokens (46.7%) out of 30).

For /nɹ/, [nɹ] (25 tokens, 83.3%) was the most frequent pronunciation and [ll] was attested in 3 tokens (10.0%) and [nl] in 2 tokens (6.7%). Thus, the influence of the Korean phonological rule on the production of the English cluster /nɹ/ was far less obvious in comparison to the cluster /nl/. The mispronunciation of the liquid involved was also found for the clusters /nl/ and /nɹ/.

Korean learners' production patterns for /ŋl/ and /ŋɹ/ are illustrated in Table 8.

Table 8. Production Patterns for /ŋl/ and /ŋɹ/

Cluster	Production	Total
/ŋl/	**[ŋl]** 28 (93.9%), **[ŋɹ]** 2 (6.7%)	30 (100%)
/ŋɹ/	**[ŋɹ]** 24 (80.0%), **[ŋl]** 6 (20.0%)	30 (100%)

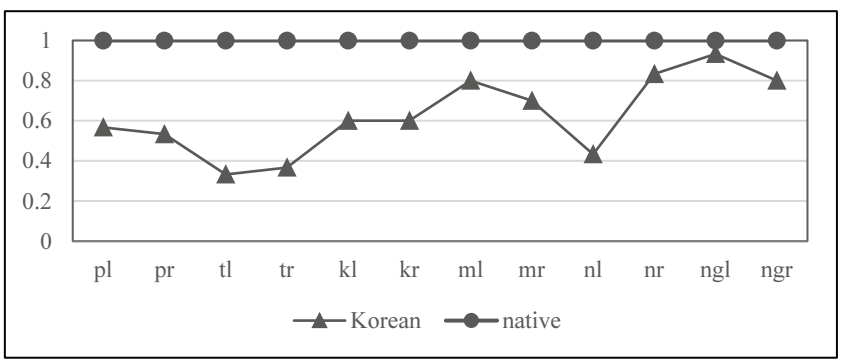
Native English speakers pronounced /ŋl/ and /ŋɹ/ as [ŋl] and [ŋɹ] respectively in all the tokens obtained from the production experiment. As shown in Table 8, Korean learners showed a similar tendency by pronouncing /ŋl/ and /ŋɹ/ as [ŋl] and [ŋɹ] respectively in most tokens. Production errors were all caused by the mispronunciation of the liquid involved.

4.2 Statistical analyses

For statistical analyses, Korean learners' accurate (i.e., native English speaker-like) pronunciation of an English biconsonantal cluster was given a score of '1' and inaccurate pronunciation a score of '0'. As mentioned in the previous section, native English speakers illustrated the same pronunciation for each cluster type. Thus, each of the native English speakers' production data was given a score of '1'.

For the 360 tokens produced by Korean learners and the 144 tokens produced by native speakers of English, an analysis of variance (ANOVA) was

run with the production accuracy as a dependent variable. Speakers' group (Korean vs. native English) and cluster type (/pl/ vs. /pɹ/ vs. /tl/ vs. /tɹ/ vs. /kl/ vs. /kɹ/ vs. /ml/ vs. /mɹ/ vs. /nl/ vs. /nɹ/ vs. /ŋl/ vs. /ŋɹ/) were independent variables. According to the analysis, significant main effects were found for group ($df = 1$, $F = 96.206$, $p < .05$) and cluster type ($df = 11$, $F = 2.109$, $p < .05$). In addition, there was a significant interaction of group * cluster type ($df = 11$, $F = 2.109$, $p < .05$). Figure 4 illustrates the finding.



Note: pr = pɹ, tr = tɹ, kr = kɹ, mr = mɹ, nr = nɹ, ngl = ŋl, ngr = ŋɹ
Figure 4. Mean production accuracy by group * cluster type

As can be seen from Figure 4, native English speakers' mean production accuracy was 1 for all cluster types. Korean learners' mean production accuracy was the highest for /ŋl/ at .933 followed by /nɹ/ at .833, /ml/ and /ŋɹ/ both at .8, /mɹ/ at .7, /kl/ and /kɹ/ both at .6, /pl/ at .567, /pɹ/ at .533, /nl/ at .433, /tɹ/ at .367, and /tl/ at .333. An ANOVA was run to see whether Korean learners' production accuracy was significantly different among the 12 cluster types and a significant main effect of cluster type was found ($df = 11$, $F = 5.352$, $p < .05$).

To see if production accuracy was different within each cluster type according to speakers' group, a series of *t*-tests was run. Significant differences were found for /pl/ ($t = 8.739$, $p < .05$), /pɹ/ ($t = 10.000$, $p < .05$), /tl/ ($t = 22.857$, $p < .05$), /tɹ/ ($t = 19.740$, $p < .05$), /kl/ ($t = 7.619$, $p < .05$), /kɹ/ ($t = 7.619$, $p < .05$), /mɹ/ ($t = 4.898$, $p < .05$), and /nl/ ($t = 14.945$, $p < .05$) between Korean and native English speakers. For /ml/, /nɹ/, /ŋl/, and /ŋɹ/, production accuracy was not significantly different according to speakers' group.

With the 504 tokens collected from the production experiment, an ANOVA was performed again to examine the effect of speakers' group, the liquid type included in a cluster, and the first consonant of a cluster on production accuracy. In the analysis, a dependent variable was production accuracy and independent variables were speakers' group (Korean vs. native English), the liquid type contained in a cluster (/l/ vs. /ɹ/), the manner of articulation of the first consonant in a cluster (C1 manner) (stop vs. nasal), and

the place of articulation of the first consonant in a cluster (C1 place) (bilabial vs. alveolar vs. velar). According to the analysis, significant main effects were found for group ($df = 1$, $F = 57.395$, $p < .05$), C1 manner ($df = 1$, $F = 23.243$, $p < .05$), and C1 place ($df = 2$, $F = 5.900$, $p < .05$). There was no significant main effect of liquid type ($df = 1$, $F = 1.453$, $p = .229$). In addition, a significant interaction of group * C1 manner was found ($df = 1$, $F = 23.243$, $p < .05$). Figure 5 illustrates the finding.

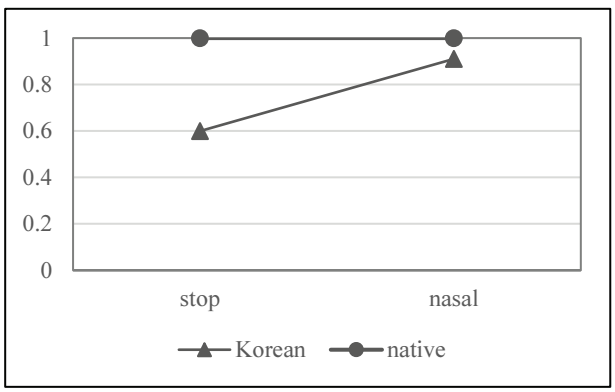


Figure 5. Mean production accuracy by group * C1 manner

As shown in Figure 5, Korean learners' mean production accuracy was significantly higher when the manner of articulation of the first consonant in a cluster (i.e., C1 manner) was a nasal (.911) than when it was a stop (.6). According to *t*-tests, mean production accuracy was significantly different between the two speaker groups both when the C1 manner was a stop ($t = 71.429$, $p < .05$) and when it was a nasal ($t = 23.810$, $p < .05$).

There was a significant interaction of group * C1 place ($df = 2$, $F = 5.9$, $p < .05$). Figure 6 shows the finding.

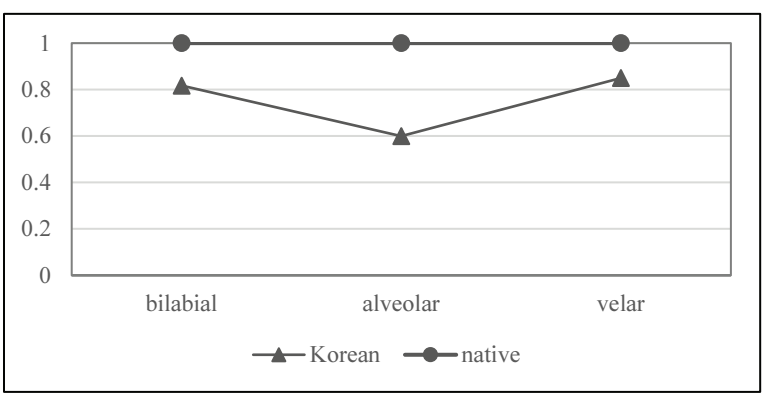
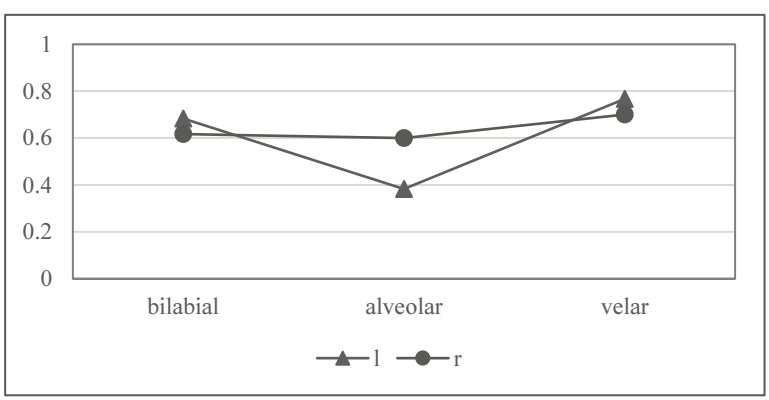


Figure 6. Mean production accuracy by group * C1 place

Korean learners' mean accuracy was the highest when the place of articulation of the first consonant in a cluster (i.e., C1 place) was velar (.85) followed by bilabial (.817) and alveolar (.6). According to a post-hoc test of LSD, there were significant differences for bilabial vs. alveolar and velar vs. alveolar ($p < .05$). On the other hand, there was no significant difference for bilabial vs. velar ($p = .505$). Thus, it can be said that Korean learners' mean production accuracy for an English biconsonantal cluster was significantly lower when C1 place was alveolar than when it was bilabial or velar. According to a series of *t*-tests, significant differences were found with mean production accuracy between the two speaker groups for all types of C1 place ($t = 25.538$, $p < .05$ for bilabial; $t = 49.036$, $p < .05$ for alveolar; $t = 17.247$, $p < .05$ for velar).

To examine factors influencing Korean learners' production of the English biconsonantal clusters, an ANOVA was performed with the 360 tokens produced by Korean learners. In the analysis, a dependent variable was production accuracy and independent variables were liquid type (/l/ vs. /ɹ/), C1 manner (stop vs. nasal), and C1 place (bilabial vs. alveolar vs. velar). According to the analysis, significant main effects were found for C1 manner ($df = 1$, $F = 27.125$, $p < .05$) and C1 place ($df = 2$, $F = 8.720$, $p < .05$). Although there was no main effect of liquid type ($df = 1$, $F = .335$, $p = .563$), there was a significant interaction of liquid type * C1 place ($df = 2$, $F = 3.871$, $p < .05$). Figure 7 illustrates the finding.



Note: r = ɹ

Figure 7. Korean learners' mean production accuracy by liquid type * C1 place

In case the second consonant of a cluster was /l/, mean production accuracy was the highest when the first consonant was velar (.767) followed by bilabial (.683) and alveolar (.383). According to an ANOVA run with production accuracy as a dependent variable and C1 place as an independent variable, there was a significant main effect of C1 place for the tokens containing /l/ ($df = 2$, $F = 11.390$, $p < .05$). A post-hoc test of LSD revealed

significant differences for bilabial vs. alveolar and alveolar vs. velar ($p < .05$). There was no significant difference for bilabial vs. velar ($p = .325$). Thus, for clusters with /l/, Korean learners' production accuracy was significantly lower when the second consonant of a cluster was alveolar. For /ɹ/, a similar pattern was found. Production accuracy was the highest when the first consonant of a cluster was velar (.7) followed by bilabial (.617) and alveolar (.6). An ANOVA was run with production accuracy as a dependent variable and C1 place as an independent variable for the Korean learners' data with /ɹ/ and there was no main effect of C1 place ($df = 2$, $F = .740$, $p = .478$). To see if production accuracy was significantly different within each C1 place according to liquid type, a series of *t*-tests was run. A significant difference was found for alveolar ($t = 5.814$, $p < .05$) and there were no significant differences for bilabial ($t = .579$, $p = .448$) and velar ($t = .674$, $p = .413$). Therefore, it can be said that Korean learners' production accuracy for the English clusters examined was significantly different according to the liquid type of a second consonant when the first consonant of a cluster was an alveolar. That is, Korean learners' production accuracy was significantly lower when the first consonant was an alveolar and the second consonant was the lateral /l/.

5 Discussion

In producing English 'consonant + liquid' clusters, Korean learners illustrated several particular patterns. First, for all cluster types examined in this study, the mispronunciation of a liquid involved (i.e., /l/ as [ɹ] and /ɹ/ as [l]) was found. This can be argued to be the result of the Korean phonology. As previously mentioned, there is no phonemic difference between [l] and [ɹ] in Korean and the liquid phoneme /L/ is realized as [l] or [ɹ] (or [ɾ]) depending on the syllable position. Considering this, it is not surprising that Korean learners occasionally mispronounced /l/ as [ɹ] and /ɹ/ as [l] when pronouncing the English clusters containing a liquid. In the present study, it was also found that the post-consonantal /l/ was pronounced as [n] by Korean learners for the English clusters /kl/ and /ml/. This can be said to be the influence of the Korean phonology again. As mentioned in section 2, in Korean, a liquid is prohibited in onset position except when a coronal consonant precedes and a liquid positioned after a non-coronal stop or nasal is realized as [n]. Thus, pronouncing /l/ as [n] after the non-coronal consonant /k/ or /m/ in English clusters is expected in Korean learners' production.

Second, the change of a stop into a nasal was attested in Korean learners' production of an English 'stop + liquid' cluster. In Korean, there is a phonological rule changing a stop into a nasal before a nasal, as can be seen from /pap + mul/ → [pammuL] 'ricewater', /tot + namuL/ → [tonnamul] 'sedum', and /hak-mun/ → [haŋmun] 'learning' (Seo et al., 2005; Shin & Cha, 2004; Sohn, 1999). In addition, as previously mentioned in section 2, in Korean

/pL/ and /kL/ are realized as [mn] and [ŋn] respectively. In the present study, interestingly, pronouncing a stop consonant as a nasal was found regardless of the change of a following liquid into a nasal. For /pl/ and /pɹ/, the pronunciation [mn] was not observed. Instead, the forms such as [ml] and [mɹ] were attested. The pronunciation [nl] was observed for /tl/ and the forms such as [nɹ] and [nl] for /tɹ/. In addition, for /kl/, [ŋl] and [ŋɹ] as well as [ŋn] were found. In case of /ŋɹ/, the forms such as [ŋl] and [ŋɹ] were attested while [ŋn] was not found. These results show that Korean learners were partially under the influence of their L1 phonology when pronouncing English 'stop + liquid' clusters. Thus, L1 phonological rules were found to influence L2 production. This is in contrast with the influence of an L1 allophonic rule. As shown in Seo (2019), when pronouncing English words including the sequence of /si/, Korean learners of English were not influenced by the Korean allophonic rule realizing /s/ as [ʃ] before a high front vowel.

Third, unlike other English clusters, Korean learners' production of /tl/ and /nl/ showed a relatively strong influence of the Korean phonology. For /tl/, [ll] was observed in 40.0 % of the Korean learners' data while the native English speaker-like pronunciation [tˀl] was attested in 33.3%. In case of /nl/, [ll] was observed at the same rate as [nl] (43.3 %). Lower native English speaker-like pronunciation was also observed for /tɹ/ (36.7%). For this cluster type, [nn] and [ll] which can be said to occur due to the L1 phonology accounted for 10.0% of the data, and other various pronunciation forms were found. For the cluster /tɹ/, Korean learners illustrated the most diverse pronunciation. The clusters /tl/, /nl/, and /tɹ/ are the ones with two consecutive alveolar consonants. According to Seo (2003), phonetic similarity between the two members of a consonant cluster triggers contrasts of weak perceptibility and thus sound alternations in a consonant cluster. According to her account, it is expected that homorganic clusters such as /tl/, /nl/, and /tɹ/ will undergo more phonological modifications than heterorganic clusters such as /pl/, /kl/, /ml/, /ŋl/, etc. However, with this account, it is not clear why there was no such strong influence of the L1 phonology for /nɹ/ which is also a cluster consisting of two alveolar consonants.

Statistical analyses of the data collected from this study revealed some important facts about Korean learners' production of the English biconsonantal clusters examined. To begin with, for /ml/, /nɹ/, /ŋl/, and /ŋɹ/, Korean learners' production accuracy was not significantly different from native English speakers. For the other cluster types, Korean learners exhibited significantly lower production accuracy in comparison to native English speakers. Those cluster types include all 'stop + liquid' clusters examined and /mɹ/ and /nl/ among the 'nasal + liquid' clusters investigated. This result cannot be explained within Seo (2003)'s similarity account. The clusters /ml/, /nɹ/, /ŋl/, and /ŋɹ/ consist of the two sonorants. Thus, contrary to the result of the present study, it is expected within the similarity account that the clusters /ml/, /nɹ/,

/ŋl/, and /ŋɹ/ will exhibit more phonological modifications (i.e. lower production accuracy) than 'stop + liquid' clusters.

According to statistical analyses, it was found that Korean learners' production accuracy of the English biconsonantal clusters examined was influenced by the manner of articulation of the first consonant (C1) of the cluster. Their production accuracy was significantly higher when C1 was a nasal consonant (.911) than when it was a stop consonant (.6). As previously mentioned, because of the partial influence of a Korean phonological rule, some Korean learners showed a tendency of nasalizing a stop consonant before an underlying liquid regardless of whether or not the liquid consonant is realized as [n]. Thus, it can be said that Korean learners' lower production accuracy for a 'stop + liquid' cluster than for a 'nasal + liquid' cluster occurred due to such a production pattern influenced by the L1 phonology.

In addition, the place of articulation of the first consonant (C1) in an English biconsonantal cluster influenced Korean learners' production accuracy. When C1 was an alveolar consonant, their production accuracy was significantly lower than when it was a bilabial or velar consonant. Thus, Korean learners' production accuracy was especially low for /tl/ (.333), /tɹ/ (.367), and /nl/ (.433). However, for /nɹ/, their production accuracy was not significantly different from native English speakers by showing mean production accuracy of .833. Furthermore, statistical analyses illustrated that the influence of C1 place was significantly different according to a liquid type. That is, when a liquid involved is /l/, there was a significant main effect of C1 place by illustrating a significantly lower production accuracy for an alveolar than for a bilabial or a velar. On the other hand, no significant main effect of C1 place was found before /ɹ/.

To sum up, Korean learners' production accuracy was significantly low when C1 was alveolar and C2 was /l/ while it was relatively high when C1 was alveolar and C2 was /ɹ/. Since both /l/ and /ɹ/ are alveolar consonants, in terms of the similarity account mentioned above, it is not clear why Korean learners' production accuracy was different according to a liquid type involved when C1 was alveolar. To find an answer for this problem, mean production accuracy of each word for the clusters /tl/, /tɹ/, /nl/, and /nɹ/ was examined. Table 9 illustrates Korean learners' mean production accuracy for the four English clusters by each of the test words.

Table 9. Production Accuracy for /tl/, /tɹ/, /nl/, and /nɹ/ by Each Test Word

Cluster Type	Word	Mean Production Accuracy	
/tl/	hotline	.5	
	outlet	.1	
	streetlamp	.4	.333
/tɹ/	footrace	.5	
	hatrack	.3	
	hitrun	.3	.367
/nl/	mainland	.4	

	moonlight	.7	
	online	.2	.433
/nɹ/	moonrock	.7	
	onrush	.8	
	sunrise	1.0	.833

As can be seen from Table 9, the clusters /tl/ and /nl/ had test words exhibiting extremely low production accuracy: *outlet* (.1) and *online* (.2). These two words are loanwords very frequently used in Korea and their pronunciation was nativized with the application of Korean phonological rules. Thus, *outlet* is pronounced as [aullɛt] and *online* as [onnain] or [ollain]. In the present study, /tl/ was realized as [ll] in 90% of the production data for the word *outlet*. In addition, for the word *online*, [nl] was pronounced as [ll] in 60% of the Korean learners' production data and as [nn] in 10% of the data. Therefore, it is clear that such loanword pronunciation contributed to a significantly low production accuracy for /tl/ and /nl/ overall. In addition, the test words such as *hatrack* and *hitrun* used for /tɹ/ seemed to be less familiar to Korean learners, resulting in low production accuracy. On the other hand, for /nɹ/ consisting of two alveolar consonants in sequence, relatively more familiar words seemed to be included in comparison to /tɹ/ and this may have caused higher production accuracy. Therefore, it can be said that Korean learners' production accuracy was also influenced by their familiarity with the test words.

6 Conclusion

This study examined Korean L2 learners' production patterns of English biconsonantal clusters (i.e., /p, t, k, m, n, ŋ/ + /l, ɹ/) and factors influencing their production. Korean learners exhibited production patterns which were different from native English speakers. First of all, due to the influence of their L1 sound inventory where [l] and [ɹ] are not contrastive, the mispronunciation of a liquid (i.e., /l/ as [ɹ] and /ɹ/ as [l]) was observed. In addition, it was found that their L1 phonological rules affecting a post-consonantal onset liquid were in play when pronouncing English clusters. Thus, for example, /tl/ was mostly pronounced as [ll] and the nasalization of a stop before a liquid was attested. Finally, Korean learners' production of the English clusters examined in this study was also influenced by phonetic similarity between the two members of a consonant cluster and their familiarity with the test words. Lower production accuracy for the clusters /tl/, /tɹ/, and /nl/ consisting of two alveolar consonants show the influence of phonetic similarity between the two members of a cluster. In addition, the influence of familiarity with the test words can be seen from the result that Korean learners exhibited especially lower production accuracy for the words *outlet* and *online*. These are frequently used as loanwords in

Korea and pronounced as nativized forms with the application of Korean phonological rules.

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Received: August 26, 2021
Revised: October 24, 2021
Accepted: November 2, 2021