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The relationship between "native-like" L2 vowel production and perceptual judgments enhancement by native listeners*

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Oh, Eunhae. 2019. The relationship between "native-like" L2 vowel production and perceptual judgments enhancement by native listeners. *Linguistic Research* 36(2), 241-261. The relationship between second language (L2) vowel production as a function of L2 experience and its perceptual judgments by native listeners of the language was investigated to determine whether the production improvement in the specific acoustics of L2 vowels give rise to higher judgement accuracy. A total of 20 Mandarin Chinese differing in the L2 experience (6 months vs. 2 years) were compared to ten native Korean speakers in their production of seven Korean vowels. The vowel production was used for an identification test by 23 native Korean speaking listeners to further verify the effects of L2 experience on the native Korean listeners' judgments of Chinese speakers' vowel production. For the analyses, F1 and F2 values of the initial vowels were measured and normalized across the three groups. The production results showed that the Korean mid vowels /ɛ/ and /ʌ/ were produced in a more native-like manner with increased L2 experience. As for the perception results, Chinese speakers' non-native-like production of Korean vowels /ɛ/ and /ɯ/ showed high judgement accuracy, whereas more native-like vowels /u/ and /ʌ/ displayed significantly lower accuracy. Overall, the acoustic distinctiveness, rather than native-likeness, of the L2 vowel categories was shown to yield higher accuracy for the perceptual judgments by native listeners. **(Konkuk University)**

Keywords L2 vowel production, effects of L2 experience, vowel perceptual judgments, cross-linguistic similarity, acoustic distinctiveness

1. Introduction

Previous cross-language research has demonstrated the effects of phonetic similarity between L1 and L2 segments on the production of L2 sounds.

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Evidence were shown to support that "new" L2 vowels without a close counterpart in the L1 are more difficult to acquire than "similar" or "identical" L2 vowels with a counterpart in the L1 (Trofimovich, Baker, and Mack 2001; Baker, Trofimovich, Flege, Mack, and Halter 2008). In Trofimovich, Baker, and Mack (2001), Korean adults were shown to map tokens of a "new" English vowel /ʊ/ onto a phonetically similar Korean vowel /u/. Baker et al. (2008) also reported that Korean adult learners of English showed difficulty acquiring two "new" English vowels /ɪ/ and /ʊ/ compared to similar vowels /i/ and /u/. One way to explain the differences may be the influence of perceptual factors (Flege 1995). The discrimination of the difference between phonemically distinct L2 sounds is influenced by the perceptual similarity between the L1 and neighboring L2 sounds.

On the other hand, the Speech Learning Model proposes that the more distant an L2 sound is from the closest L1 speech sound, the more learnable the L2 sound will be (Flege 1995: 233). For instance, Guion et al. (2000) showed that more accurate acquisition of English /ɹ/ than /l/ by Japanese speakers is due to the greater phonetic difference between Japanese /ɾ/ and English /ɹ/. Oh et al. (2011) found that Japanese children acquired "new" English lax vowels faster with higher accuracy than adults in a year's time. The study also found phonetic category dissimilation between the newly established L2 category and the similar L1 speech category in child production. In Guion (2003), simultaneous and early bilinguals of Quichua (L1) and Spanish (L2) were shown to acquire Spanish vowels similar to Spanish monolinguals. The late bilinguals, however, were less likely to produce Spanish vowel categories that are distinct from the adjacent Quichua vowels.

The age effects on the success of acquiring "new" L2 vowels have been explained in the framework of the Interaction Hypothesis which highlights the interactive dynamics of the L1 and L2 systems (Flege 1999; Walley and Flege 1999). That is, the degree and direction of the L1 and L2 interaction vary as a function of the development of the L1 phonetic system at the time of L2 learning. In Baker and Trofimovich (2005), for example, Korean child bilinguals assimilated Korean /ɛ/ to English /ɪ/ and Korean /ɯ/ to English /u/, whereas the adult bilinguals with the same amount of English language experience (i.e., seven years) assimilated Korean /i/ to English /ɪ/ and Korean /u/ to English

/ʊ/. The differing nature of cross-language mapping between child and adult bilinguals suggests that the more the L1 is established, the more likely it is that learners will filter L2 sounds through the closest sounds in the L1 inventory.

Along with the substantial effects of age, L2 experience has also been shown to influence the L2 learners' ability to create "new" L2 vowel categories independently from L1 vowel categories. For example, Flege (1987) found that experienced English learners of French were able to acquire a "new" L2 phone (French /y/) in a native-like way, whereas the "similar" L2 phones (/u/ and /t/) were identified as L1 counterparts. However, unlike the well documented effects of L2 experience on children's L2 production (Flege et al. 1997; Ingram and Park 1997; Tsukada et al. 2005), it still remains controversial as to what extent the role of L2 experience contributes to the ultimate L2 attainment in adult learners' speech production. In previous studies, a substantial body of evidence showed that no amount of L2 experience can completely override the language experience acquired from the outset. Tsukada et al. (2005), for example, compared the English vowels produced by Korean adults with three and five years of L2 experience to those by native English speakers. They found that adult learners were not able to acquire English vowels regardless of the length of L2 experience. Flege, Bohn and Jang (1997) examined the production and perception of English /i/ and /ɪ/, /ɛ/ and /æ/ by L2 learners with four different L1 backgrounds. L2 learners with approximately seven years of English language experience overall outperformed inexperienced learners with seven months of L2 exposure in making L1-L2 phonetic contrasts. However, notwithstanding their extensive L2 exposure to English, not one of the experienced L2 groups was completely native-like.

More recently, Holliday (2016) underlined the difference between 'more versus less' and 'some versus none'. He argued that having some knowledge of L2 phonology and orthography can rather bias L2 learners to perceive the same acoustic cues differently from naïve learners. In the study, Naive, novice and advanced Mandarin speakers were compared to the native Korean speakers for the /sh/-/s*/ perceptual assimilation, discrimination and identification tasks. Results showed naive listeners were more accurate than novice learners who had more experience with Korean at discriminating the two sounds in the /a/ context. The results were interpreted to suggest that naive listeners were more

likely to be keen on the lower-level acoustic cues, which may have been obscured by top-down information for L2 learners with some experience.

Moreover, what is less clear is whether the improved or native-like L2 production leads to higher accuracy in perceptual judgments by native listeners of the language. As for the implications of "native-like" productions, the bulk of studies have suggested meaningful correlation between the production and perception. According to SLM, accurate production may be perceptually based. Namely, improved perception of the difference between L1 and L2 vowel categories is thought to give rise to more native-like L2 vowel production. Flege (1995) reported that Korean learners of English were not able to discriminate English /i/-/ɪ/, and thus were unable to produce the vowel pairs in a native-like manner. Yoon (2007) examined the perceptual similarity for English /ɛ/ and /æ/ by inexperienced and experienced Korean speakers. The results showed that the experienced speakers were more likely to identify the English /æ/ as a distinct L2 vowel category which reportedly yielded more accurate production of the "new" L2 vowel. In Sakai and Moorman (2018), L2 perception training was also shown to have a medium-sized improvements in perception and a smaller yet significant improvements in production. The authors reported greater improvements for obstruents than sonorants or vowels, suggesting the difference in the magnitude of the production effect sizes depending on the type of L2 speech sounds.

If greater L2 experience and training can lead to improvement in their perception as well as production of L2 vowel categories, one might expect to find higher accuracy for native listeners' perceptual judgments of the improved vowels. In Flege et al. (1997), the production of /i/-/ɪ/ and /ɛ/-/æ/ by 20 speakers each of German, Spanish, Mandarin, and Korean speakers was identified by three native English speaking listeners. More often than not, the experienced L2 learners were shown to produce English vowels more accurately than inexperienced learners in all four groups. In particular, the Korean experienced learners made more use of spectral than temporal cues compared to the inexperienced learners, resulting in higher identification judgements. However, it should be noted that the experienced learners' /ɪ/s, which were significantly different from the native English speakers' production, were correctly identified 92% of the time, suggesting that the relationship between the

L2 speakers' improvement in the specific acoustic properties and its effect on listeners' perception may not always be straightforward.

2. Current Study

As aforementioned studies have helped unravel the nature of a production-perception link within individual speakers, the current study sought to add to the body of knowledge and determine whether the production improvement in the specific acoustic cues in L2 vowels as a function of L2 experience can be taken as an index of improved intelligibility. The current study investigated the following questions: 1) Does L2 experience result in more native-like production of L2 vowel categories? Additionally, do "new" L2 vowels with no apparent L2 counterparts show greater improvement than "similar" L2 vowels with increasing experience? 2) Can we assume that acoustically native-like vowels produced by experienced L2 speakers are judged as accurately as those produced by native speakers of the language? To this end, the study reported here examined seven Korean vowels produced by two groups of Chinese learners of Korean with varying amount of Korean language experience. These vowels' spectral acuity was assessed via an identification task performed by native speakers of Korean.

First, it was hypothesized that experienced Chinese speakers would show greater improvement in their production of "new" vowels in Korean. Under the assumption that L2 learners are able to create separate phonological representations for the L1 and L2 sounds as they gain experience in the L2, experienced Chinese speakers were expected to establish distinctive Korean vowels independently from the Chinese vowels. Kim (2013), for example, examined the Korean vowels produced in the CV(C) structure by 23 Chinese learners a total of five times across a one-year period. The results showed that, even within a year time, Chinese speakers were able to establish more distinctive L2 vowel categories. However, the study reports faster acquisition of cross-linguistically similar vowels such as /i/ and /a/ than those without apparent counterparts such as /e/, /o/ and /ㅡ/. Notably, Chinese speakers showed greater difficulties acquiring accurate F2 values (tongue advancement)

than F1 values (tongue height). This may be due to the influence of the crowded Chinese vowel categories along the F2 dimension. Ryu (2018) showed that Korean /i/, /a/ and /o, u/ are acoustically most similar to Mandarin Chinese /i/, /ɑ/ and /u/, respectively, and thus can be expected to be easier for Chinese L2 learners. Based on the five-vowel system in Mandarin Chinese (Lin 2010), the mid vowels in Korean such as /e/, /ʌ/, /ɯ/ and /o/ are relatively "new" to Chinese speakers. In the current study, the term "new" vowels, defined as Korean vowels without a close counterpart in Chinese, and "similar" vowels, defined as Korean vowels having a counterpart in Chinese, are chosen only to readily refer to the relative degree of similarity between the L1 and L2 vowels.

Secondly, in order to examine the effects of production improvement on the enhancement of perceptual judgments, native Korean listeners were asked to attend to the phonetic details of the vowels produced by Chinese speakers and identify each vowel they heard. The prediction was that native Korean listeners would show higher accuracy for vowels produced in a native-like manner. The experienced Chinese speakers were expected to outperform less experienced Chinese speakers in both production and perception experiments. The study will take a glance at what it means for L2 learners to acquire L2 vowels in a more native-like fashion via the ears of native listeners.

3. Methods

3.1 Participants

Participants for the production study were 20 native speakers of Mandarin Chinese and age-matched 10 native speakers of Seoul Korean (NK), who were all college students (Mean age = 22.6) at the time of testing. More experienced Chinese students had received on average 3 years (Mean length of residence = 3.4) of education at a University in Seoul, Korea. Experienced Chinese students took three hours of Korean language classes five days a week for three years. Less experienced Chinese students had resided in Korea approximately three months and had no prior experience learning Korean at the time of testing. All Chinese speakers indicated Mandarin as their only native language. None of the

Chinese speakers had experience learning Korean or English outside the classroom setting in China.

As for the perception experiment, 23 native speakers of Seoul Korean were recruited. They were all college students (Mean age = 23.6) and had no experience living abroad for more than three months. None of the participants reported any speech or hearing disorders.

3.2 Speech material and procedure

For the production experiment, a total of 14 easy and frequent words were presented via pictures on a computer screen. Seven Korean vowel categories represented in fourteen words, two words exemplifying each vowel category, were produced by all of the participants (see Table 1). Orthography was not provided to avoid spelling effects. In order to familiarize the inexperienced Chinese speakers with the stimuli, all of the participants were given the auditory cue for the first two presentations. Only the two tokens randomly repeated after the familiarization trials, namely the non-cued productions, were analyzed. Because vowels were compared across groups, and not across words, the surrounding consonantal context was not thought to compromise the results. Participants were recorded individually in a sound-proof room by using a Shure KSM10 microphone and a Tascam (HD-P2) solid-state recorder.

Table 1. Korean vowels produced in isolation

Vowel	Words	
/a/	/kaji/ 'branch'	/kabaŋ/ 'bag'
/ɛ/	/kɛmi/ 'ant'	/kɛkaŋ/ 'beginning school'
/i/	/kirin/ 'giraffe'	/kiʧa/ 'train'
/o/	/kogi/ 'meat'	/koɾɛ/ 'whale'
/u/	/kuɾɯm/ 'cloud'	/kumʌŋ/ 'hole'
/ɯ/	/kɯrim/ 'painting'	/kɯnɯl/ 'shade'
/ʌ/	/kʌmi/ 'spider'	/kʌɾi/ 'street'

After the production task, the vowel portion of the first syllable was excised from the target word and normalized to 50% peak intensity before they were

randomly presented to the native Korean-speaking listeners. The independent samples *t*-test showed that vowels produced by the inexperienced Chinese speakers were longer than the experienced Chinese and native Korean speakers ($p < .05$). However, the vowel length was not manipulated to provide natural sounds.

For the perception experiment, the Korean listeners were presented to the segmented audio stimuli in a random order, using Praat 6.0 with a 1-second interval between presentations. A total of 420 tokens (14 words x 30 speakers) were given to 23 native Korean-speaking participants for a forced-choice task with seven choices. They were asked to press one of the seven vowels presented in Korean orthography on a computer monitor with a mouse. There was a five second time limit but they were able to listen to the same stimuli two times within the time frame. The experiment took approximately 20 minutes and they were compensated for their time.

3.3 Acoustical measurements

A total of 840 tokens (14 words x 2 repetitions x 3 groups x 10 participants) for the Korean vowel productions were analyzed. All vowels were measured from the onset of the first periodic wave to the offset of the last one observed in both the waveform and the spectrographic display. In addition, first and second formant frequencies of each vowel were measured at the temporal midpoint of the vowel. All formant frequency values were normalized using the Lobanov (1971) method which converted all formant values to z-scores for each subject.

4. Results

4.1 Production experiment

First, the native-likeness of the Chinese learners' Korean vowel production was assessed and compared to that of the Native Korean group. The production of seven Korean vowels by the NK (native Korean), Experienced and

Inexperienced groups were compared, using SPSS 24. The dependent variables were F1 and F2 frequencies and the independent variables were seven Vowels (/a/, /ɛ/, /i/, /o/, /u/, /ɯ/, /ʌ/) and three Groups (Experienced, Inexperienced, Native Korean). In the case of a significant interaction between Group (3) and Vowel (7), eight MANOVAs were conducted to test the effect of Group on each Vowel. The alpha level was adjusted to 0.007 for seven comparisons. The univariate tests for F1 and F2 are reported for each significant MANOVA comparison. The F1 and F2 frequencies obtained at the temporal midpoint were compared and the analysis returned a significant Group effect [$F(4, 52) = 8.498$, $p < 0.05$, $\eta p^2 = 0.395$] as well as a significant Group and Vowel interaction [$F(12, 208) = 2.396$, $p < 0.05$, $\eta p^2 = 0.118$]. Thus, all three pairings of the groups were compared (i.e., NK vs. Exp, NK vs. Inexp, Exp vs. Inexp). First, in order to examine the native-likeness of the Korean vowels produced by the Experienced and Inexperienced groups, the Chinese groups were separately compared to the NK group. Figure 1(a) and (b) display the F1 and F2 frequency distributions for the NK and the Experienced group, respectively. A MANOVA on the normalized F1 and F2 frequencies of Korean vowels produced by the NK and Experienced groups revealed a significant effect of Group [$F(2, 17) = 12.976$, $p < 0.05$, $\eta p^2 = 0.604$] and a significant Group by Vowel interaction [$F(12,214) = 2.396$, $p < 0.05$, $\eta p^2 = 0.118$]. Seven MANOVAs testing the effect of Group on each Vowel showed significant effects for the high back vowels, /o/ [$F(2, 17) = 13.353$, $p < 0.007$, $\eta p^2 = 0.611$] and /u/ [$F(2, 17) = 14.843$, $p < 0.007$, $\eta p^2 = 0.636$] and marginally for the low back vowel /a/ [$F(2, 17) = 6.446$, $p = 0.008$, $\eta p^2 = 0.431$].

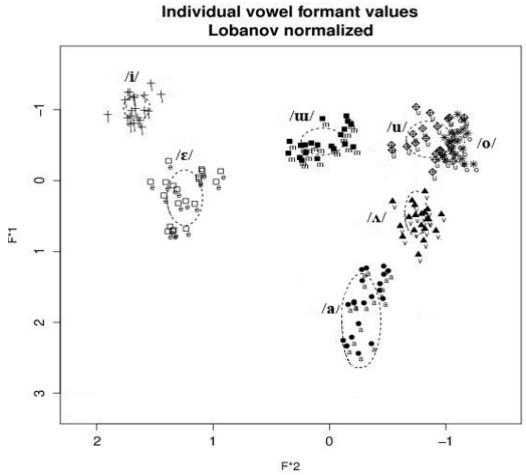
Accordingly, the univariate tests for the F1 and F2 frequencies for the two significant MANOVA comparisons were conducted. The Experienced group produced /o/ [$F(1, 18) = 22.822$, $p < 0.007$, $\eta p^2 = 0.559$] and /u/ [$F(1, 18) = 16.673$, $p < 0.007$, $\eta p^2 = 0.481$] with substantially higher F2 frequency values (indicated with an arrow in Figure 1(b)). It should be noted that, as in the NK group, the Experienced group made a clear category distinction between the near merging /o/ and /u/ vowels in F2 frequency [$F(1, 9) = 29.135$, $p < 0.007$, $\eta p^2 = 0.764$]. That is, the two vowels were produced as distinctive vowel categories, albeit in a nonnative-like manner. As shown in Figure 1, there was a significant difference in F2 frequency for /ɯ/, but only in the univariate test [$F(1, 18) =$

10.863, $p < 0.007$, $\eta p^2 = 0.376$] with the Experienced group producing /ɯ/ with higher F2 values (i.e., more fronted) than the NK group. Overall, the Experienced group produced the Korean vowels with a high degree of accuracy except for the two distinctive back vowels that are produced with a relatively more fronted tongue position.

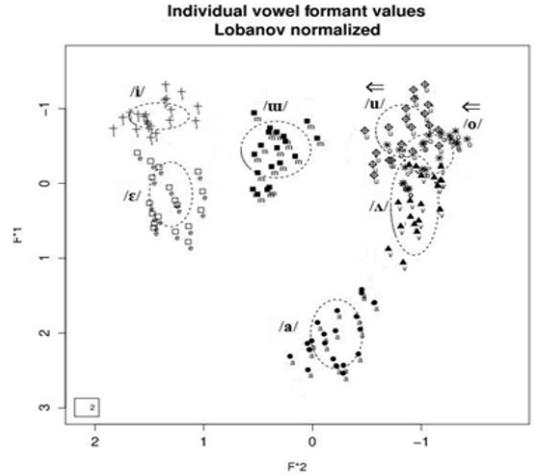
Next, the NK and the Inexperienced group's productions were compared. Figure 1(c) displays the F1 and F2 frequency distributions for the Inexperienced group. A MANOVA on the F1 and F2 frequencies produced by the NK and Inexperienced groups revealed a significant effect of Group [$F(2, 17) = 7.230$, $p < 0.05$, $\eta p^2 = 0.460$] as well as a significant Group and Vowel interaction [$F(12, 214) = 5.939$, $p < 0.05$, $\eta p^2 = 0.250$]. To further investigate which vowels were significantly different across groups, each vowel was submitted to MANOVAs. The effect of Group on each Vowel showed significant effects for /ɛ/ [$F(2, 17) = 11.406$, $p < 0.007$, $\eta p^2 = 0.573$], /o/ [$F(2, 17) = 16.706$, $p < 0.007$, $\eta p^2 = 0.663$] and /ʌ/ [$F(2, 17) = 27.129$, $p < 0.007$, $\eta p^2 = 0.761$]. In the univariate tests, the Inexperienced group's production showed a significantly lower F1 frequency for /ɛ/ [$F(1, 18) = 17.462$, $p < 0.007$, $\eta p^2 = 0.573$] and /ʌ/ [$F(1, 18) = 27.129$, $p < 0.007$, $\eta p^2 = 0.761$] and a significantly higher F2 frequency for /o/ [$F(1, 18) = 18.355$, $p < 0.007$, $\eta p^2 = 0.505$]. The vowels that are significantly different from the NK group's vowels are indicated with an arrow in Figure 1(c). The results suggest that the Inexperienced group produced the two mid-vowels /ɛ, ʌ/ with lower F1 (i.e., higher in the vowel space) and /o/ with higher F2 frequencies (i.e., further front in the vowel space) than the NK group. Also as clearly illustrated in Figure 1(c), the three back vowels /o, u, ʌ/ did not statistically differ from one another ($p < .05$). These results indicate that the three back vowels were not produced distinctly, suggesting an assimilated category for Korean /o/-/u/-/ʌ/ in terms of formant frequencies (See Figure 2(c)).

To examine the effect of L2 experience, the Experienced and Inexperienced groups' productions were compared. A MANOVA revealed a significant effect of Group [$F(2, 17) = 5.462$, $p < 0.05$, $\eta p^2 = 0.391$] and a significant Group by Vowel interaction [$F(12,214) = 2.210$, $p < 0.05$, $\eta p^2 = 0.110$]. Seven MANOVAs testing the effect of Group on each Vowel showed a significant effect for /ʌ/ [$F(2, 17) = 5.462$, $p < 0.05$, $\eta p^2 = 0.391$]. In the univariate tests, /ʌ/ showed a significant increase in a F1 frequency for the Experienced group. Although the MANOVA

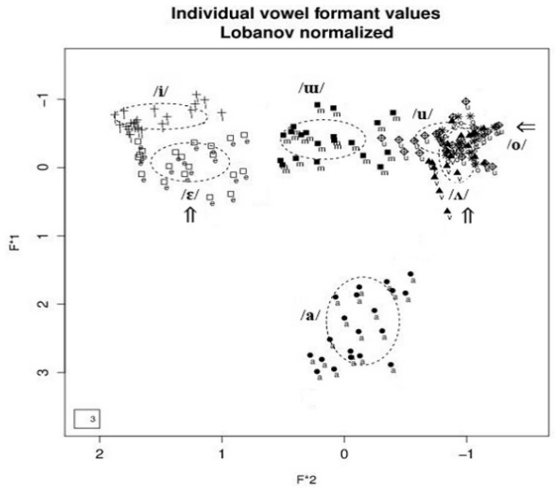
test for /ɛ/ was only marginally significant (p = .02), the univariate test showed a significant increase in F1 values [$F(1, 18)$ = 9.138, p = 0.007, ηp^2 = 0.337]. As shown in Figure 1(b) and (c), the mid vowels were produced with an increased F1 frequency (lower), suggesting the development of more distinct (i.e., less overlapping) specific vowel categories in Experienced group's production.



(a) Seven Korean vowels produced by ten native Korean speakers



(b) Seven Korean vowels produced by ten Experienced Chinese learners



(c) Seven Korean vowels produced by ten Inexperienced Chinese learners

Figure 1. Ten (a) native Korean, (b) Experienced and (c) Inexperienced Chinese speakers' productions of seven Korean vowels are shown. Each dot represents an individual vowel production. Vowels that differed significantly from the NK group (panel (b), (c)) are marked with a double arrow pointing in the direction of the difference.

Taken all together, Chinese learners were able to produce the three peripheral vowels, /i, u, a/ in a native-like manner from the outset. After two years of experience, they have shown to acquire the mid vowels /ɛ, ʌ/ with greater height distinctions from adjacent vowels. Although the two high back vowels /o, u/ were statistically different from the native norm, the Experienced group have learned to distinguish the vowels along the F2 dimension (i.e., front-back). Following the examination of the effects of L2 experience on vowel production, the ensuing question is whether these notable improvements in production are also shown in perception by native Korean-speaking listeners. Under the assumption that phonetic accuracy leads to auditory acuity, the significant effects demonstrated especially for /ɛ/ and /ʌ/ were expected to show greater improvement in perception.

4.2 Perception experiment

A total of 420 tokens (14 words x 3 groups x 10 speakers) were given to 23

native speakers of Seoul Korean for a forced-choice task with seven choices. Judgment accuracy was coded as correct if they matched the vowel intended by the talker. An ANOVA revealed significant main effects of Group [$F(2, 462) = 62.345$, $p < .05$, $\eta p^2 = .213$], Vowel [$F(6, 462) = 131.842$, $p < .05$, $\eta p^2 = .631$] as well as the Vowel by Group interaction [$F(12, 462) = 38.871$, $p < .05$, $\eta p^2 = .502$] were significant.

First, the Inexperienced group was compared to the NK group to examine whether the non-native-like vowels were also perceived less native-like compared to those produced by the native Korean speakers. The results returned significant main effects of Group [$F(1, 308) = 111.729$, $p < .05$, $\eta p^2 = .278$], Vowel [$F(6, 308) = 65.877$, $p < .05$, $\eta p^2 = .562$] and a Vowel by Group interaction [$F(6, 308) = 48.730$, $p < .05$, $\eta p^2 = .487$]. As shown in Figure 2, the NK group received higher judgement accuracy scores for /u/ [$F(1, 44) = 65.977$, $p < .007$, $\eta p^2 = .600$], /o/ [$F(1, 44) = 19.128$, $p < .007$, $\eta p^2 = .303$], and /ʌ/ [$F(1, 44) = 115.103$, $p < .007$, $\eta p^2 = .723$]. Note that the tokens of /ɛ/, which were produced in a non-native-like way, were perceived as accurately as those produced by the NK group.

When the Experienced group was compared to the NK group, the main effects of Group [$F(1, 308) = 51.419$, $p < .05$, $\eta p^2 = .143$], Vowel [$F(6, 308) = 74.526$, $p < .05$, $\eta p^2 = .592$] as well as the interaction between Group and Vowel [$F(6, 308) = 55.244$, $p < .05$, $\eta p^2 = .518$] were all significant. Similarly, three vowels showed significantly lower accuracy for the Experienced group: /u/ [$F(1, 44) = 138.667$, $p < .007$, $\eta p^2 = .759$], /o/ [$F(1, 44) = 54.305$, $p < .007$, $\eta p^2 = .552$], /ʌ/ [$F(1, 44) = 19.008$, $p < .007$, $\eta p^2 = .302$]. However, as seen in Figure 2, tokens of /ɯ/ [$F(1, 44) = 41.590$, $p < .007$, $\eta p^2 = .486$] produced by the Experienced group were identified with greater accuracy than those produced by the NK group. As shown in Figure 1(b), the lower F2 values (more fronted) may have facilitated the identification of the centered vowel.

In order to examine the effects of L2 experience, the Experienced and Inexperienced groups were compared. The results showed significant main effects of Group [$F(1, 308) = 20.155$, $p < .037$, $\eta p^2 = .061$], Vowel [$F(6, 308) = 147.724$, $p < .037$, $\eta p^2 = .742$] and a Group and Vowel interaction [$F(2, 462) = 20.060$, $p < .037$, $\eta p^2 = .281$]. As shown in Figure 2, two vowels, /ʌ/ [$F(1, 44) = 47.017$, $p < .007$, $\eta p^2 = .517$] and /ɯ/ [$F(1, 44) = 23.012$, $p < .007$, $\eta p^2 = .343$], were identified more accurately for the Experienced group.

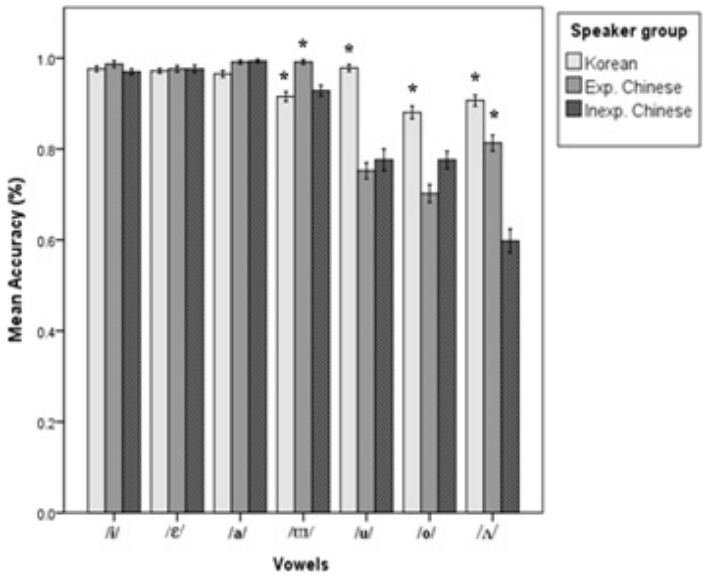


Figure 2. Mean judgment accuracy for seven Korean vowels produced by three speaker groups and judged by 23 native Korean listeners is shown. An asterisk indicates that the group differed from the group(s) on its right-hand side.

Because the listeners had to base their judgments solely on a limited set of lower-level acoustic cues, even vowels produced by the native speakers of Korean were poorly identified by the native listeners (see Lee 2014). However, judging from the results shown in the Figure 2, the back vowels were more likely to be misidentified than the front vowels, especially for the two Chinese groups. In addition, in line with previous literature, peripheral vowels (i.e., /i/, /a/, /u/) produced by native Korean speakers tend to show greater judgment accuracy than central vowels (i.e., /ɯ/, /o/ and /ʌ/). The detailed results are shown in Table 2. The mean errors for the NK group showed high accuracy for /i/, /ɛ/, /a/ and /u/ and comparatively lower accuracy for /ɯ/, /o/ and /ʌ/. As a result of the raising (a decrease in F1 frequency) of /o/ toward /u/ in Korean (Seong 2005; Moon 2007; Han and Kang 2013), the identification of /o/ was less accurate (13% error rate) than that of /u/ (2% error rate).

Notably, the non-native-like production of /ɯ/ by the Experienced group showed the highest accuracy. As can be seen in Table 2, the NK group's production of /ɯ/ was higher in the error rate (6%) than the Experience group's

production with only 1% of misidentified tokens. As a result of the increased F2 values, all of the Experienced group's /ɯ/ tokens were judged as /ɛ/, whereas the NK or Inexperienced groups' /ɯ/ was mistaken for one of the back vowels such as /ʌ/, /u/ and /o/. Recall that these three back vowels were not produced as distinctive categories in the Inexperienced group's production. With a significant improvement as a function of L2 experience, however, the Experienced group was better at distinguishing /ʌ/ from the back vowels /u/ and /o/. On the one hand, the improvements in spectral qualities were also confirmed by the substantial decrease in the number of errors from 40% to 19%. On the other hand, considering that native-like productions of /ʌ/ was observed for the Experienced group, their comparatively lower judgment accuracy suggests that other acoustic cues may have been at play.

Table 2. Mean error in percent for each vowel in identification task (Number of instances heard as /V/ is indicated in parentheses and a significant difference between groups is indicated with a star)

Vowel	Inexperienced	Experienced	Native Korean
/i/	2% (/ɛ/:11)	1% (/ɛ/:5)	3% (/ɛ/:14)
/ɛ/	2% (/i/:8, /ɯ/:2)	2% (/i/:7, /ɯ/:3)	3% (/i/:12)
/a/	0% (/ʌ/:2)	1% (/ʌ/:4)	2% (/ʌ/:7)
/ɯ/	8% (/ʌ/:23, /u/:7, /o/:5)	1% (/ɛ/:4)	6% (ʌ/:20, /u/:7)
/u/	21% (/o/:86, /ɯ/:11)	28% (/o/: 85, /ɯ/:43)	2% (/ɯ/:7, /o/:2)
/o/	22% (/ʌ/:47, /u/:32, /ɯ/:20)	46% (/ʌ/:98, /u/:92, /ɯ/:22)	13% (/u/:57, /ʌ/:5)
/ʌ/	40% (/o/:159, /ɯ/:23)	19% (/o/:47, /ɯ/:30, /a/:12)	9% (/o/:40, /ɯ/:2)

5. Discussion

The results of the production study align with previous findings in showing that there was a significant effect of L2 experience on vowel productions coupled with the influence of L1 vowel categories, which determined the direction and the extent of the effect. The phonetic similarities between L1 and L2 vowel

systems provide a basic overview of what to expect when it comes to the rate and order of vowel acquisition. As for Korean and Chinese, the peripheral vowels /i/, /u/ and /a/ are cross-linguistically similar, and thus can less likely pose a challenge to the L2 learners. The results obtained in the production task confirmed that these vowels were native-like even without much experience with Korean language (see Figure 1(c)). The fact that Chinese speakers chose /i/ and /a/ as two of the easiest Korean vowels to learn (Kim 2009) supports the relative ease of native-like production and low error rates.

Besides the three peripheral vowels, /ɯ/ was also native-like in both Inexperienced and Experienced groups' productions, and its early acquisition indicates that a "similar" L1 vowel may have facilitated L2 category learning. The acquisition of /ɯ/ in the current study did not confirm the findings in Kim (2013)'s longitudinal study which showed that Chinese learners of Korean were not able to produce /ɯ/ in a native-like manner within a year time. In Kim (2013), Chinese participants were asked to read controlled non-word stimuli (CV or CVC) in a given phrase, whereas the current study used real words in isolation. Due to diverse allophones of the phoneme /ɜ/ in Chinese, the context in which the target vowel was produced determines the phonetic properties of the phoneme. Thus, the context in this study with potentially wider allophonic distribution of phoneme /ɜ/ may have created greater overlap between the two phonetically similar vowels in phonetic space (see Zhang, Chen, Yan, Wang, Chen, and Shi 2016). Also, it has been reported that younger Korean speakers tend to front /ɯ/ more than older speakers (Jang, Shin, and Nam 2015). The raising of F2 values for /ɯ/ observed in the Experienced group's production is assumed to reflect the change, resulting in a significantly high identification accuracy by the young Korean listeners due to its greater distinctiveness from the high back vowels.

The "new" vowels were less native-like than the "similar" vowels in Inexperienced group's production. Especially, /ɛ/ and /ʌ/ with no close counterpart in Chinese appeared to be more difficult for the Inexperienced group. Both vowels were produced with significantly higher F1 values by the Inexperienced group, which may be due to the lack of mid vowel categories in the Chinese five-vowel system. However, the degree of the non-native-likeness for the two vowels were different in that /ɛ/ was distinctive from the

neighboring high front vowel /i/ in spectral qualities, whereas /ʌ/ was assimilated to the nearing high back vowels /o/ and /u/. The difference in the distinctiveness of the /ɛ/ and /ʌ/ was manifested in perceptual judgment accuracy as well (/ɛ/: 98%, /ʌ/: 60%). With a couple of years of experience, however, both of the vowels were produced and perceived with higher accuracy. The relatively fast improvement of these mid vowels should be interpreted with caution as the participants' previous experience with these vowels via the L3, English, may have played a part in the acquisition of L2 phonetic categories.

The nonnative-like or delayed acquisition of /o/ and /u/ conforms to the pattern shown in previous research (Kim 2009; Kim 2013; Yun, Kim, and Seong 2015). Kim (2013) reported that /o/ and /u/ are the difficult vowels to acquire for Chinese learners. In Kim (2009), most of the errors shown in /o/ was produced as either [oʌ] or [oʊ̈]. Even highly experienced Chinese learners of Korean confused /o/ for either /ʌ/ or /u/ in many cases. An explanation may be found in Mandarin Chinese where [o] and [uo] are in complementary distribution: [o] only appears after a labial initial (Yuan 2013). Considering that the initial consonant for all of the stimuli was velar /g/ in the this study, Korean /o/ might have been diphthongized, if there was any influence of L1 phonology. The accurate production of Korean /u/ by the Inexperienced group can also be interpreted as the effect of the phonetically similar monophthong /u/ in Chinese. However, the Experienced, but not the Inexperienced, speakers were able to create separate categories for /o/ and /u/, despite the apparent effects of L1 and the reduced acoustic distance between /u/ and /o/. Namely, the Experienced L2 speakers have learned to differentiate /u/ from /o/ along the F2 dimension, which was shown to be an informative cue for female speakers of Seoul Korean (Kong and Kang 2018).

Finally, some discrepancies between production and perception results should be addressed. On the one hand, the non-native-like production of /ɛ/ by the Inexperienced group (98%) and /ɯ/ by the Experienced group (99%) showed a high level of judgment accuracy by the Korean listeners. On the other hand, the native-like production of /u/ by the Inexperienced group (79%) and /ʌ/ by the Experienced group (81%) received significantly lower judgement accuracy compared to those produced by the NK group (91% and 98%, respectively). Taken together, native-like spectral accuracy measures did not directly translate

into the same degree of native-like perceptual accuracy. Rather, phonetic distinctiveness of the vowel category in perceptual vowel space appear to be more relevant to understanding improved vowel identification accuracy. In the current study, Korean vowels produced by the Chinese learners were presented to the listeners in a random fashion. However, blocking the stimuli will allow listeners to adjust to relative distinctiveness among vowels in phonetic space for each speaker, possibly leading to higher judgement accuracy. Further pursuit of this issue is left for future research.

So far, many studies have focused on the native-likeness of L2 sounds as a way to measure the success of L2 speakers' production, and the assessment was often made in comparison to native speakers of the given language in spectral and/or temporal domains. The current study suggests that native-likeness in production should not be assumed to yield accurate judgments by native speakers of the language. Regardless of whether it was perceived as native or not, non-native-like L2 vowels can be identified accurately when produced with sufficient phonetic distinctiveness within the L2 vowel system. The findings here in both production and perception, however, must be interpreted with caution as the vowel inherent spectral change or their temporal cues have not been taken into account.

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