Linguistic Research 35(1), 233-251
DOI: 10.17250/khisli.35.1.201803.009

Effects of L2 experience on the production of Korean stop contrasts by Mandarin Chinese learners*

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Oh, Eunhae. 2018. Effects of L2 experience on the production of Korean stop contrasts by Mandarin Chinese learners. *Linguistic Research* 35(1), 233-251. Effects of L2 experience on the segmental and prosodic production of second language were investigated. Thirty two Chinese learners of Korean varying in the amount of experience (3 months vs. 2 years) were compared to sixteen age-matched native Korean speakers in their production of three-way contrastive stops (aspirated, lenis, tense). Korean four-syllable phrases (i.e., Accentual Phrase) beginning with each stop type in a word-initial position were elicited. VOT, F0, H1-H2 values of the segments as well as an Accentual phrase-initial boundary tones were analyzed and compared across groups. The results showed significant differences in F0 and H1-H2 as a result of experience, albeit F0 was not native-like in the experienced group's production. The Accentual phrases-initial boundary tones, however, were produced with a native-like F0 pattern regardless of the amount of L2 experience. The native-like production of VOT and F0 in the tonal context in both L2 groups is likely to be the influence of L1, whereas the improved cues, H1-H2 and F0 in the segmental context, are the result of L2 experience. **(Konkuk University)**

Keywords effects of L2 experience, Korean three-way stop contrast, F0, VOT, H1-H2, segmental and tonal context

1. Introduction

The language-specific categorization of three-way laryngeal stops (lenis, tense, aspirated) in Korean has long been a subject of interest for largely two reasons. First, the phonological cue that played a major role in distinguishing the three stop types in contemporary Seoul Korean has undergone a diachronic shift (Cho, Jun, and Ladefoged 2002; Silva 2004; Silva, Choi, and Kim 2004; Wright 2007; Kang and Guion 2008; Kang 2014). The difference used to be primarily characterized by VOT

* This paper was supported by Konkuk University in 2017. I thank the anonymous reviewers for their insightful and thoughtful comments.

with aspirated stops being the longest followed by lenis and tense stops. Recent studies, however, have shown that younger speakers distinguish aspirated from lenis stops primarily with higher F0 on the following vowel instead of longer VOT (see Holliday and Kong 2011; Kang and Han 2013). Dialectal differences were also found. Lim and Han (2014), for example, examined Kyungsang and Seoul Korean speakers' production and perception of word-initial stops in English to compare the influence of phonetic features in the L1 dialect. In perception, Kyungsang dialect listeners showed greater sensitivity to VOT but less sensitivity to F0 compared to Seoul listeners in distinguishing English voiced and voiceless stops. The use of F0 to cue lexical tone contrast in Kyungsang dialect was attributed to the differences in acoustic cues for the L2 stop contrast. Similarly, Lee, Politzer-Ahles, and Jongman (2014) examined the dialectal difference in cue weighting for the Korean stop contrast and showed greater contribution of F0 in making lenis responses for Seoul than Kyunsang listeners. The dialectal differences have shed light on the importance of taking the detailed phonetic features and tonal systems of the L1 dialects into account on the acquisition of L2.

Secondly, with each Korean stop type produced with its own phonological cue that uniquely distinguishes one from another, non-native Korean speakers whose L1 differs in the use of acoustic correlates of stop contrasts are likely to experience difficulty separating the phonetic categories in a native-like manner (Kang and Guion 2006; Shin 2007; Holliday 2015). The degree of native-likeness in L2 stop production has been shown to vary with several factors such as phonological similarities between the L1 and L2, the age of L2 acquisition (AOA), as well as the amount of exposure to the L2. For instance, Shin (2007) provided evidence of L1 transfer in L2 production by comparing acoustic properties of Korean laryngeal stops produced by speakers of tone (Chinese, Taishanese) and non-tone (English) languages. After a perceptual training, English speakers showed improvement in the use of VOT as a result of short-(voiced) and long-lag (voiceless) VOT distinction in their native language. Tone language speakers, on the other hand, were able to utilize F0 in addition to VOT, suggesting that the early exposure to the acoustic cues in the L1 can facilitate the acquisition of the cue in the L2.

In addition, age at onset of L2 acquisition has long been studied as the most influential factor in L2 learning. Kang and Guion (2006) examined early (mean AOA = 3.8) and late (mean AOA = 21.4) Korean-English adult bilinguals'

production of English and Korean stops. The goal was to investigate the effect of age of L2 learning on the degree of separability between the L1 and L2 phonological systems. The results revealed that early bilinguals were able to establish five independent L1 and L2 stop categories, whereas late bilinguals showed assimilation of L2 categories (English voiceless and voiced stops) to L1 categories (Korean aspirated and tense stops, respectively). Early learners have been shown to exceed in establishing L2 vowel categories as well (Guion 2003; Baker and Trofimovich 2005). These studies suggest that early bilinguals are not only faster but also more accurate in creating L2 phonetic categories that are distinct from the L1.

A proposed explanation for differences in acquiring novel L2 sounds rests upon the idea that the degree of L2 production accuracy may be limited by perceptual factors (Flege 1981, 1995; Ioup 1995). According to the Perceptual Assimilation Model (PAM) espoused by Best (1994, 1995), the discrimination of nonnative sounds is influenced by the perceptual similarity between L1 and L2 sounds and the perceptual similarity has also been suggested to affect L2 speech learning (Best and Tyler 2007). Best and Tyler (2007) further noted the significant role of experience in L2 acquisition across all ages.

The difficulty of acquiring Korean stop categories is not limited to adult L2 learners. Developmental studies have shown that monolingual Korean children acquire some phonetic contrasts later than others. Kim and Stoel-Gammon (2009) examined the developmental trajectory of the three-way contrast in terms of VOT, F0 and H1-H2 and found that children began to form a bimodal contrast between tense and aspirated/lenis stops at the age of 3, suggesting their early sensitivity to VOT distinction. Although the use of F0 revealed gradual development with increase in age, the F0 distinction across the stop types were not adult-like even at the age of 4.

Considering the developmental pattern, early Korean bilinguals' mastery of the Korean stops shown in Kang and Guion (2006) not only manifests the importance of early L2 exposure but also indicates the role of constant experience with the language thereafter. The effect of L2 experience is well reported in Flege and Eefting (1988), whereby groups of Spanish-English bilingual children (mean age = 8-9), early and late bilingual adults differing in the age of L2 acquisition as well as L2 experience imitated the synthesized production of /ta/ and /da/ with VOT ranging from [-60ms] to [+90ms]. Spanish monolingual speakers generally showed lead and

short-lag distinction while English monolingual speakers showed short- and long-lag VOT distinction. However, Spanish bilinguals who spoke English on a regular basis produced stops with VOT values falling into all three modal VOT ranges (i.e., lead, short-lag, long-lag) regardless of the age of L2 exposure. The results may be interpreted to suggest that not only the age of L2 learning but also the amount of L2 experience influence the way VOT continuum is (re-)categorized.

1.1 Current study

Korean has a three-way laryngeal contrast of voiceless stops and affricates and three categories are differentiated primarily by three acoustic cues: VOT, F0, and H1-H2. Aspirated, lenis stops are produced with distinctively longer VOT than tense stops. The voice quality (captured in the amplitude difference between first and second harmonics in the following vowel) provides additional cue to separate tense from the other two phonation types. F0 of the following vowels is known to distinguish aspirated and tense stops from lenis stops (Lisker and Abramson 1964; Kim 1994; Cho, Jun and Ladefoged 2002; Kang and Guion 2008). More recent studies reported that the VOT difference between word-initial aspirated and lenis stops is slowly replaced by F0 difference among young generation (Silva 2006; Kang and Guion 2008; Kang 2014). The change in the role of VOT in distinguishing the three stop categories in Korean was also observed in Chinese Korean's production. Jin (2008) examined 22 native Chinese Korean speakers (age ranging from 20 to 72) from Korean community of Shěnyáng, China. Korean stop consonants extracted from an hour-long interview was analyzed and compared across age groups. Despite the geographical and cultural distance, older speakers used VOT as the primary cue to distinguish the stops whereas younger speakers showed a merger in VOT between aspirated and lenis stops, manifesting a similar pattern shown in young Seoul speakers' production.

Korean and Mandarin Chinese stops are similar in that they are all phonetically voiceless. However, Mandarin stops and affricates are distinguished primarily with VOT with aspiration differentiating two phonemic categories: VOT ranges from 14 to 27ms. for Mandarin voiceless unaspirated stops and 78 to 86ms. for voiceless aspirated stops depending on the place of articulation (Chen, Chao, and Peng 2007).

Affricates are produced with longer VOT, ranging from 46ms. for unaspirated affricates to 123ms. or longer for aspirated affricates.

Due to the language-specific categorization of VOT for stop types, L1 can affect the way L2 learners perceive the VOT continuum. In Lai (2013), a total of thirty Korean learners of Mandarin Chinese produced a list of Mandarin stops and affricates. The results showed that Korean learners made significant errors in distinguishing aspirated and unaspirated Chinese stops with VOT even after years of experience. Korean has two types of aspirated stops (i.e., aspirated and lenis) which is primarily distinguished by F0 and if Koreans produced Chinese aspirated stops with Korean lenis stops, the role of VOT in distinguishing aspirated (i.e., lenis) and unaspirated (i.e, tense) stops can be predicted to be smaller.

The opposite case, which examined the Chinese learners of Korean stops, also revealed an effect of a phonological contrast of the native language. In Holliday (2015), six Mandarin Chinese speakers' production of Korean stops was examined across three time points during their stay in Korea (i.e., initial stage, after 6 months and 12 months). The results revealed wide variation in stop production across speakers and there was only one Chinese speaker was shown to acquire three stops with a near native-like VOT and F0 pattern. Many exhibited a two-way VOT contrast between short- (tense) and long-lag stops (lenis, aspirated), presumably due to the influence of the native language.

Another longitudinal study on Chinese learners' production of Korean stops found an earlier mastery of VOT over F0 at the outset of the developmental trajectory. In Han and Kim (2014), Chinese speakers' developmental pattern of Korean stop production was compared across six times at two-month intervals for one year. With VOT and F0 cues put together, tense stops showed the most pronounced improvement over a year time whereas lenis and aspirated stops showed relatively delayed improvement resulting in non-nativelike onset F0 values with little improvement across all testing periods.

Besides the proposed explanation of slower acquisition of Korean stop contrast, the fact that many of the previous studies asked naïve participants to read nonsense words may not only pose a considerable effect of orthography but also yield unnatural production for a subsequent perceptual judgement. Moreover, considering the rather surprisingly slow acquisition of F0 contrast by tone language speakers may be explained in terms of the different use of F0 between L1 and L2. Previous

studies have elicited the production of mono- or multi-syllabic words to examine the F0 of each stop type. However, the acquisition of F0 for a segmental contrast may be challenging for Mandarin Chinese speakers as the use of the cue in their native language is to distinguish lexical or grammatical meaning. As F0 plays an important role in defining higher-order domains in Mandarin Chinese (Swerts 1996), the assumption is that the use of F0 would be more native-like in a prosodic unit, Accentual Phrases (AP). The tone pattern of the AP in Seoul dialect varies depending on the laryngeal feature of phrase-initial segments (Jun 1996; Cho and Lee 2016). Aspirated and tense phrase-initial consonants are realized with high F0 and lenis with low F0, which are respectively realized as High (aspirated, tense)-High-Low-High and Low (lenis)-High-Low-High tone patterns in the AP domain.

As previous research has yielded differences in terms of the degree of native-like production for Chinese learners of Korean, the current study sought to add to the body of knowledge and determine whether Chinese speakers show similar pattern with phrase-level stimuli. First, VOT and F0 differences across the three stop types are compared across groups with different amount of Korean language experience with the goal of examining the experiential effects on the acquisition of language-specific cues in the L2. Secondly, the AP boundary tones (i.e., H-H, L-H) were examined as a function of L2 language experience. The prediction was that speakers of Mandarin Chinese where tone is lexically contrastive would better exploit the F0 property of Korean in supra-segmental than segmental context with increased L2 experience.

2. Methods

2.1 Participants

The data were collected from 48 adult participants. The participants were divided into three groups of 16 each (14 female and 2 male in each group): native monolingual speakers of Seoul Korean (NK), less experienced Mandarin Chinese speakers (Inexperienced) had resided, at the time of testing, in Korea for less than 3 months (Mean = 2.6 months) and more experienced Chinese speakers (Experienced)

had been in Korea for longer than 2 years (mean = 2.3 years). The participants were all students (Mean age = 23.8) at the same college and the Chinese participants were taking Korean language classes three times a week for two hours every day. The less experienced Chinese participants were enrolled in level 1 (beginner) and the experienced participants were in level 3 (advanced). All Chinese speakers indicated Mandarin as their only native language. None of the Chinese speakers had experience learning English outside the classroom setting in China. Participants were free of speech and hearing problems as determined by self-report and a pure-tone hearing screen.

2.2 Speech material and procedure

A total of 9 phrase-initial target syllables produced in four-syllable Korean Accentual phrases were prepared to elicit three pairs of voiceless lenis, aspirated, and tense obstruents (stops and affricates) differing in places of articulation (alveolar, post-alveolar, velar). As shown in Table 1, it was important to choose phrases that occur frequently and were familiar enough to be imageable for the elicitation procedure, especially for less experienced Chinese participants. The participants produced the sentences in a delayed sentence-repetition task (see Trofimovich and Baker 2006) to avoid elicited imitation and to encourage the participants to produce the target word in their own terms. For instance, the participants first heard the question pre-recorded by a male Korean speaker ([namʤanin muʌl hanajo?] “what is the man doing?”) and then the question was followed by a response also pre-recorded by a female Korean speaker (“(He) _____”). Each participant was asked to listen to the question again and then repeat the response they heard in a female voice. Images that illustrate the phrases were presented to the participants on the screen of a desktop computer in order to make sure that the participants understood the meaning of the response they heard. Participants repeated each of the phrases three times in random order. Speakers were recorded individually in a sound-proof booth by using a Shure KSM10 microphone and a Tascam (HD-P2) solid-state recorder.

Table 1: Korean Stops Produced in Accentual Phrases

Aspirate	Lenis	Tense
/t͡ʰat.sim.ni.ta/ 'to ride'	/t͡at.sim.ni.ta/ 'to close'	/t͡*at.sim.ni.ta/ 'to pick'
/tɕ͡ʰat.sim.ni.ta/ 'to kick'	/tɕ͡at.sim.ni.ta/ 'to sleep'	/tɕ͡*at.sim.ni.ta/ 'to squeeze'
/k͡ʰʌt.sim.ni.ta/ 'to grow'	/k͡ʌt.sim.ni.ta 'to walk'	/k͡*ʌt.sim.ni.ta/ 'to turn off'

2.3 Acoustical measurements

VOT (in milliseconds) of stops and affricates was calculated as the time from the onset of the noise burst to the onset of the first clear periodic cycle of the waveform for the initial vowel of the target syllables. None of the Korean stops were prevoiced.

The amplitudes (in decibel) for the first (H1) and the second (H2) harmonics were measured at the beginning of the vowel as an indicator of voice quality (Cho et al., 2002). The spectral frames were calculated with a hamming window of duration 25ms and FFT points of 1024.

F0 (in Hertz) was measured at the temporal midpoint of each vowel in the first two syllables of the Accentual Phrases. Vowel onset was determined from the onset of the periodic waveform to the stop or nasal coda with reference to spectrograms.

2.4 Statistical analyses

Due to the differences in speech rate across participants, VOT was normalized by dividing the raw VOT measurement by the duration of the first syllable. As F0 also varies by individual, each F0 value produced by a given participant was divided by the mean value of all the midpoint measurements for that participant. Although H1-H2 values have been reported to vary by vowel quality (Fant 1960) as well as place of articulation of the preceding consonant (Delattre, Liberman, and Cooper 1955), the analysis is not compromised as each stop type is compared across group, and thus, is compared within the same phonological environment.

In order to determine whether a difference existed between the measures of

normalized VOT, F0, and mean H1-H2, three-way, group (NK, Experienced, Inexperienced) by stop type (Aspirated, Lenis, Tense) by place (alveolar, post-alveolar, velar) multivariate repeated measures analysis was conducted. The measures of normalized F0, mean H1-H2, and VOT values were submitted as dependent variables. In case of interaction, MANOVAs examined group effects on each stop type. The alpha level was adjusted to 0.017 for 3 comparisons.

3. Results

3.1 Effects of experience on the acquisition of each stop type: Between-group analyses

The results returned significant effects for group [$F(6, 404) = 3.449$, $p = .002$], stop type [$F(6, 404) = 348.526$, $p = .000$], and place [$F(6, 404) = 10.383$, $p = .000$]. The group × stop type [$F(12, 404) = 22.917$, $p = .000$] and stop type × place interactions [$F(12, 404) = 7.263$, $p = .000$] were significant. However, the interactions of group × place [$F(12, 404) = 1.793$, $p = .129$] and group × stop type × place [$F(24, 404) = 1.164$, $p = .265$] were not significant. As results indicated, group differed by stop type and thus the effect of group on each stop type was separately examined. Because place of articulation did not significantly differed across group and stop type, its effect was not further examined.

Separate MANOVAs revealed a significant effect of group for aspirated [$F(6, 278) = 5.695$, $p = .000$], lenis [$F(6, 278) = 7.419$, $p = .000$] and tense stops [$F(6, 278) = 6.120$, $p = .000$]. Pairwise comparisons showed that normalized F0 values for aspirated [$F(2, 143) = 17.089$, $p = .000$] and lenis stops [$F(2, 143) = 13.874$, $p = .000$] and mean H1-H2 values for tense stops [$F(2, 143) = 14.229$, $p = .000$] were significantly different across groups. As illustrated in Figure 1, the normalized F0 values for aspirated and lenis stops were significantly different across all three groups ($p < .017$). The Experienced and Inexperienced Chinese groups produced a significantly lower F0 for aspirated and higher F0 for lenis stops than the NK group, yielding a smaller F0 difference between aspirated and lenis stops. Note, however, that the Experienced group was considerably closer to the native norm than the Inexperienced group for both stop types. Tense stops did not differ across groups.

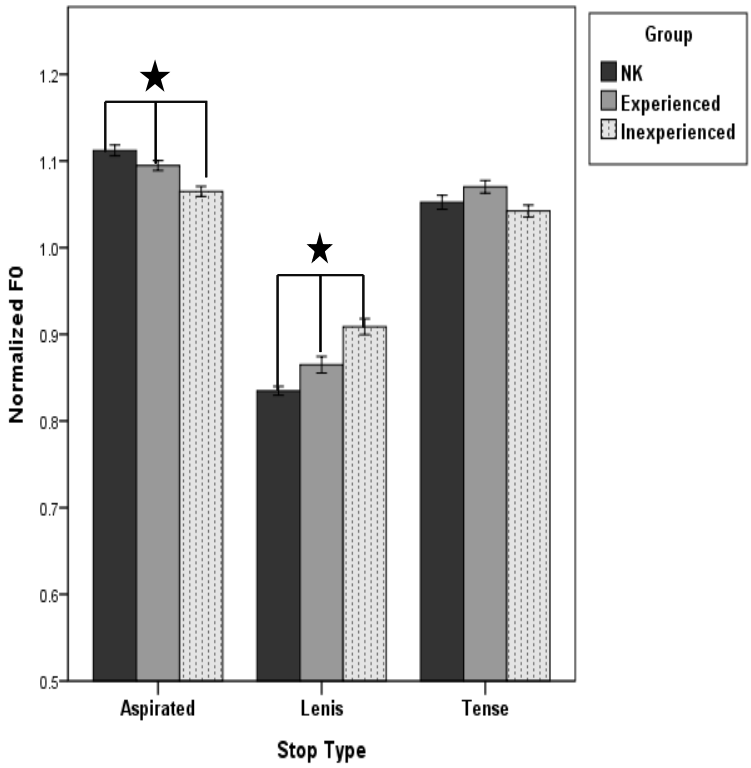

Figure 1: Normalized F0 for Korean aspirated, lenis, tense stops by the NK, Experienced and inexperienced groups are shown.

The mean H1-H2 values of aspirated and lenis stops were not significantly different across group. The values of tense stops, however, returned a substantial distinction between the NK, Experienced groups and the Inexperienced group (p < .017). As shown in the Figure 2, the Experienced group did not differ from the NK group in producing a negative H1-H2 difference for tense stops. The Inexperienced group, on the other hand, showed higher H1-H2 values indicating much weaker creakiness for tense stops in the voice quality. Inexperienced group appeared to distinguish tense stops with creakier phonation than the other two stops, albeit not in a fully native-like manner.

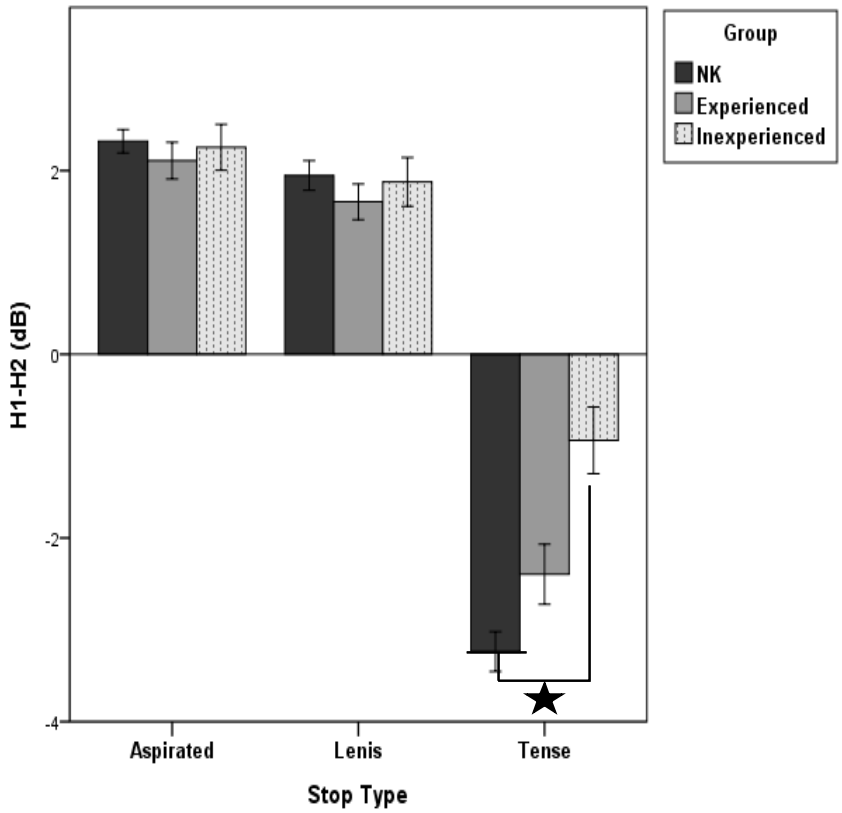

Figure 2: Mean H1–H2 (in decibel) for Korean aspirated, lenis, tense stops by the NK, Experienced and inexperienced groups are shown.

Normalized VOT values (see Figure 3) did not return a significant group effect for any of the three stop types ($p < .017$). Although VOT for aspirated and lenis stops appear to be shorter in the NK group's production, it was not statistically significant. The place of articulation differed across stop type [$F(2, 189) = 4.508$, $p = .002$] showing the shortest VOT values for alveolar stops. However, the place did not interact with group in any way which suggests that the effect of place was consistent across stop type for the three groups.

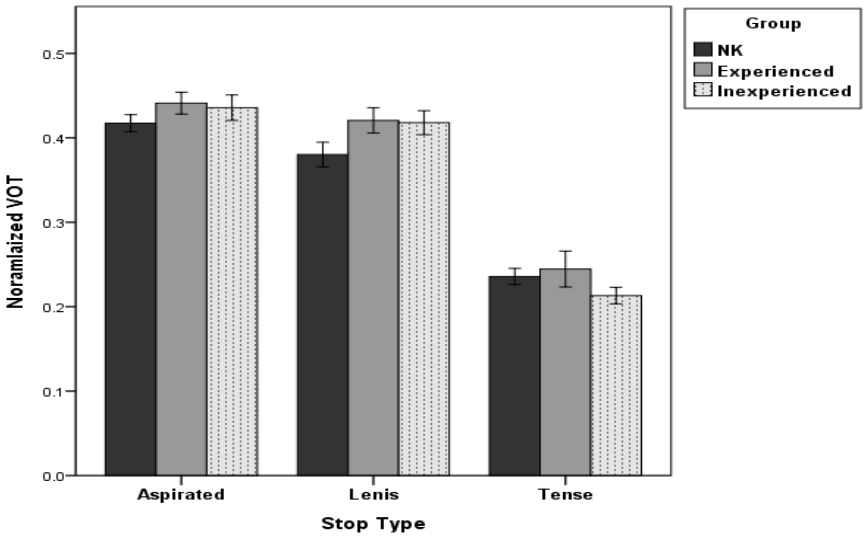

Figure 3: Normalized VOT for Korean aspirated, lenis, tense stops by the NK, Experienced and inexperienced groups are shown.

3.2 Effects of Experience on the Degree of Contrast: Within-group analyses

The analyses on the effects of group for each stop showed how native-like the production of the three stops were in their measures of normalized F0, VOT and mean H1-H2 values. However, the effect of experience on the extent of differences made with the observed measures among the stop types is less clear. Thus, each group was examined separately for within-group analyses.

First, MANOVAs were conducted to examine the three measures across stop type for the NK group. The comparison results revealed that the NK group distinguished all three stop types with F0 ($p < .0017$). As indicated by the horizontal dotted lines in Figure 4(c), normalized F0 alone separated the three stop types with aspirated stops exhibiting the highest F0 and lenis stops the lowest.

Although the fine F0 distinction between aspirated and tense stops were not observed, both Chinese groups were able to separate lenis stops from the aspirated and tense stops with lower normalized F0 and the difference increased to a much greater extent for the Experienced group. As marked with arrow in Figure 4(b), aspirated and

lenis stops moved further away from each other along the F0 dimension with increased L2 experience. However, high variability across tokens together with the non-native-like F0 values for lenis stops in the Experienced group's production suggest that lenis and aspirated stops are not clearly distinguished in terms of F0. Although differences in H1-H2 values were distinctive for tense stops in all groups (p < .017), only the Experienced group were able to produce the differences in a native-like manner.

As for the normalized VOT, all three groups showed a clear two-way VOT distinction between aspirated, lenis stops and tense stops as shown by the vertical dotted line in Figure 4.

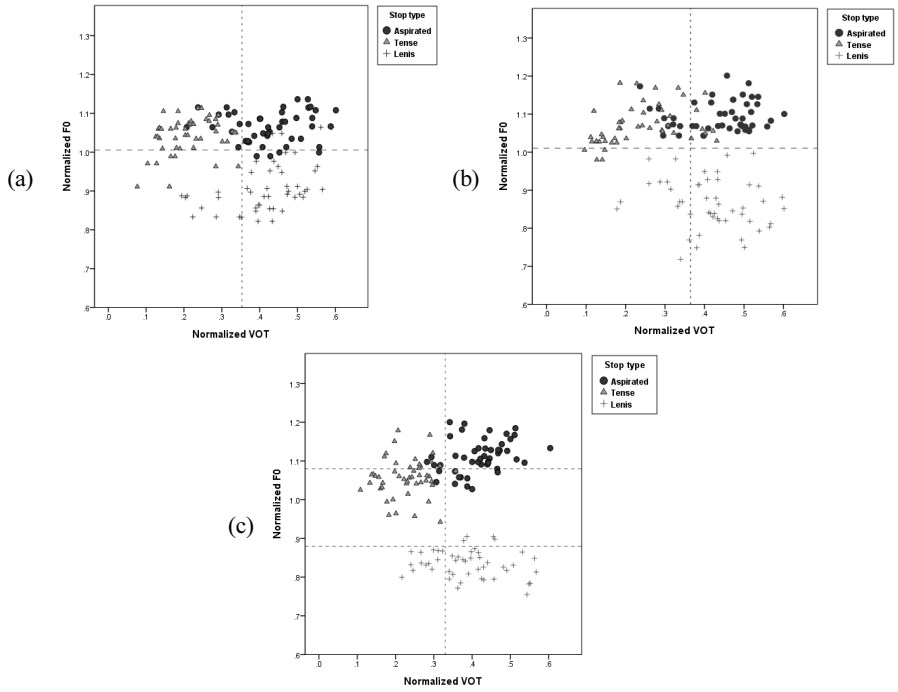

Figure 4: The production of VOT (x-axis) and F0 (y-axis) for Korean aspirated, lenis and tense stops by the Inexperienced (a), Experienced (b) and NK groups (c) are shown.

3.3 The acquisition of F0 in prosodic context

Given the results of the Experienced group's non-native-like production of F0 (at

a segmental level) for Korean stop contrast pose a question as to whether they were able to acquire the phrase-initial segmentally-induced F0 contrasts (i.e., High-High for aspirated and tense and Low-High for lenis stops). If the tonal contrast in the AP domain is acquired, we may be able to assume that the Chinese speakers acquired the some knowledge of underlying representation of Korean intonation (Jun 1996).

To this end, the raw F0 differences between the first two syllables of the AP were compared across groups. The results of three-way, group by stop type by place, ANOVAs with dependent measures of raw F0 differences returned a significant main effects of stop type [$F(2, 431) = 145.282$, $p < .000$] and place [$F(2, 431) = 6.715$, $p = .001$]. The interaction between group x stop type [$F(4, 431) = 2.957$, $p = .020$] was significant, suggesting that the group effect depended on stop type. Separate ANOVAs on each stop type showed a significant effect of group for lenis [$F(2, 143) = 6.651$, $p = .002$]. The post hoc test returned a significant difference between the Experienced and the Inexperienced groups ($p < .017$). Both groups, however, did not differ from the NK group. As in Figure 5, the Experienced group made slightly (and insignificantly) greater F0 difference for the lenis-initial syllables than the NK group, whereas the Inexperienced group made slightly (and, again, insignificantly) smaller F0 difference. The result may be interpreted as the Experienced group's trend toward exaggerating the LH pattern with greater F0 distinction than the native norm. The aspirated and tense stops did not differ across groups ($p > .017$). Overall, the basic HH and LH tonal patterns in Korean were realized in a native-like manner by both groups.

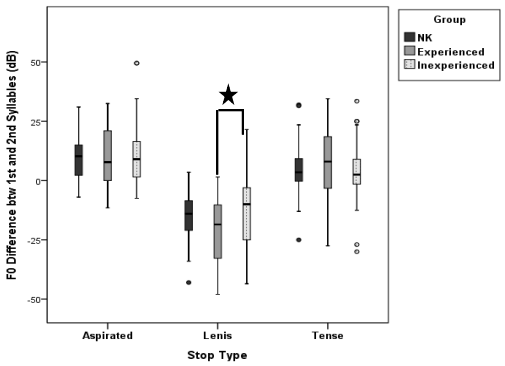

Figure 5: Raw F0 difference between first and second syllables for Korean aspirated, lenis and tense stops by the NK, Experienced and Inexperienced groups is shown.

4. Discussion

The effects of L1 as well as L2 experience on the acquisition of the L2 stops are shown. First, VOT for the three stop types and the F0 patterns of the AP-initial and -second syllables were produced in a native-like manner by the Mandarin speaking participants regardless of the amount of experience in Korean. The assumption is that the loss of VOT contrast between aspirated and lenis stops in Korean, resulting in two-way VOT distinction similar to the stop system in Mandarin have facilitated the learning of tense and non-tense categories. Also for the acquisition of segment-induced F0 patterns of the AP, both Mandarin speaking groups did not deviate significantly from the native norms. As speakers of a tonal language, Mandarin speakers are apt to be sensitive to the changes in F0 of syllables (Gottfried and Suiter 1997) and this prior L1 experience may have attracted their attention to the F0 variation throughout syllables of the AP[1]. As Flege's Speech Learning Model (Flege 1995) indicated, Lim and Han (2014) verified, L2 phonetic features that are used to signal phonological contrasts in L1 were shown to facilitate L2 learning.

Other acoustic properties manifested improvement as a result of L2 experience. The normalized F0 by the Inexperienced group was significantly lower for aspirate and higher for lenis, yielding a small F0 distinction between aspirated and lenis stops, whereas the F0 of lenis stops was considerably lower in the Experienced group's production as a result of longer exposure to Korean. What should be noted is the contrasting result of the experiential L2 effect on the production of F0 in segmental and prosodic contexts. Namely, the three-way F0 distinction for segmental contrast was deviant from the native norm even after two years of exposure whereas the tonal patterns across AP boundaries were produced in a native-like manner after a short period of L2 experience. This result is interpreted to suggest that the acquisition of F0 contrast at the segmental level may be more challenging to the Mandarin learners than the F0 patterns at the higher-order prosodic context, arguably due to the phrase-level at which the cue is used in Korean is analogous to that in Chinese. It may also be the case, as Holliday (2015) suggested, that Chinese speakers did not simply notice the use of F0 as an important cue to the Korean stop contrast at the segmental level at least in the initial stage.

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1 Note that the Korean production by the Inexperienced Mandarin speakers may not represent the initial state as they were also exposed to some Korean (2.6 months) at the time of testing.

Among the three stop types, tense stops were acquired faster than the other types. That is, all three measures were mastered as a function of experience. The early acquisition of tense stops has already been documented in Chinese learners of Korean (Lei Lei and Kim 2011; Han and Kim 2014) as well as Korean-speaking children's production studies (Jun 2007; Kong, Beckman, and Edwards 2011). For example, Kong et al. (2011) examined the relative order of mastery of the different stop types in Korean children's production. Despite the greater motoric demands, tense stops were mastered earlier due to their heavy reliance on a single acoustic parameter, VOT. Namely, tense stops can be easily differentiated from non-tense based solely on VOT, whereas a clear distinction between lenis and aspirated stops requires the acquisition of both F0 as well as VOT. Along similar lines, Mandarin speakers' native-like acquisition of tense stops may likely be the influence of L1 knowledge as they can readily employ VOT, compared to F0, to discriminate stop types. Lei Lei and Kim (2011) found that Mandarin Chinese learners with less than 6 months of experience in Korean were able to produce tense stops in a native-like manner whereas the difficulty was shown in producing sufficient F0 difference between lenis and aspirated stops. The relative difficulty acquiring detailed phonetic features may be due to the mis-matching of cross-language category mapping. Namely, Korean tense stops are likely to have mapped to Mandarin Chinese unaspirated stops whereas Korean aspirated and lenis stops to Mandarin Chinese aspirated stops, resulting in faster and more accurate acquisition of Korean tense stops. Additional factors such as the lower frequency of tense stops in Korean adult speech and its perceptual saliency due to the creaky voice quality (H1-H2) can be noted as factors facilitating early learning of tense stops (Jun 2007).

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Received: 2017. 10. 17.
Revised: 2018. 02. 28.
Accepted: 2018. 02. 28.