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L2 Production of Non-contrastive Sounds in L1*

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This paper investigates L2 production of particular sounds which are not contrastive in L1. L2 production data of nonce words by adult Korean learners of English were collected along with production of native speakers of English. Specifically, L2 production of English [s] and [ʃ] were compared with [z] and [ʒ] in order to answer the question of whether the relative similarity or difference with L1 and L2 sounds or the absence of phonological features would create learning difficulty to L2 learners. In doing so, both common and different acoustic characteristics between Korean L2 learners of English and native speakers of English were examined. According to the results, L2 learners showed better production with [s] and [ʃ], non-contrastive but allophonic sounds of the same phoneme in L1. Learners experienced more difficulty with [z] and [ʒ], non-contrastive and non-occurring sounds in L1.

[L2 production/English alveolar and palato-alveolar fricatives/non-contrastive sounds]

I. INTRODUCTION

Every language has different sound inventories. For example, English and Korean are different in terms of the types and numbers of fricatives; English fricatives are realized in five different places, both in voiceless and voiced (i.e., labio-dentals – /f, v/, dentals – /θ, ð/, alveolars – /s, z/, palato-alveolars – /ʃ, ʒ/, and glottal – /h/) whereas Korean fricatives are all voiceless, and realized in only two different places (i.e., /s, s', h/). In particular, although /ʃ, z, ʒ/ are not phonemes in Korean, [ʃ] can occur as a variant of /s/ before the

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vowel /i/ or the palatal glide /j/ (Sohn, 1999). In contrast, [z] and [ʒ] do not surface at all in Korean. For this reason, Korean L2 learners of English are expected to face different kinds of learning problem with [s, ʃ] and [z, ʒ].

In terms of L2 learners' difficulty, researchers have rendered different views. For example, according to Flege (1995), we can construe that learners will experience more difficulty with [s, ʃ] than [z, ʒ]. According to his Speech Learning Model (SLM), learners will discern a difference between L1-L2 sounds more easily when the perceived phonetic dissimilarity between an L2 speech sound and the closest L1 sound is greater. According to the pilot study mentioned in Lim and Seo (2008), Korean learners of English map the English fricatives [s, ʃ] onto the Korean fricative [s] or [s'] while they do the English fricatives [z, ʒ] onto the Korean affricate [tɕ]. This result shows that the perceived phonetic dissimilarity is greater with English [z, ʒ] and Korean [tɕ] than with English [s, ʃ] and Korean [s, s']. Hence, learning is more likely to occur with [z, ʒ] due to their differences with Korean sound system. With [s, ʃ], learning may be more difficult, since the differences with L1 system may not be as discernible to Korean L2 learners of English.

Brown (2000), however, shows a different prediction in that learning difficulty is not merely affected by similarities or differences between L1 and L2. Rather, acquisition of certain L2 contrasts is influenced more by the fact that "the phonological feature that underlies that particular acoustic dimension exists independently in the learners' native grammar" (p. 20). For example, although English [l] and [r] do not correspond to distinct segments in Chinese and Japanese, the coronal feature distinguishing [l] and [r] is employed in differentiating other segments in Chinese. Thus, according to Brown, Chinese learners were shown to acquire English [l] and [r] contrast more easily than Japanese learners whose native language lacks the feature. Likewise, [s] and [ʃ] are not distinct segments in Korean, and the same is true for [z] and [ʒ]. Additionally, the Korean language does not employ the phonological feature distinguishing alveolars and palato-alveolars. Hence, Korean learners are expected to face the same degree of difficulty in differentiating [s] from [ʃ] and [z] from [ʒ].

Based on the different views aforementioned, the goal of this study is to investigate Korean L2 learners' acquisition of [s] and [ʃ] and also [z] and [ʒ]. To this end, a production experiment was designed with nonce words. By using nonce words, it allows us to constrain the contextual environment where these segments occur so as to compare acoustic cues occurring within the same context. Also, nonce words enable us to look at segments free from word frequency effect. Specifically, following research questions were tested in the present study:

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(1) What are the common acoustic characteristics between [s] and [ʃ] and between [z] and [ʒ] as produced by Korean L2 learners of English and native speakers of English?
(2) What are the different acoustic characteristics between [s] and [ʃ] and between [z] and [ʒ] as produced by Korean L2 learners of English and native speakers of English?
(3) Would Korean L2 learners of English face similar or different learning difficulties between [s, ʃ] and [z, ʒ]?

II. METHOD OF RESEARCH

1. Participants

The production experiment was conducted with 10 Korean learners of English (five males and five females[1]). All of the participants were students at a certain University in Seoul. They formed a rather homogenous group according to their English proficiency levels; their average TOEIC scores were in the 500s. Additionally, four native speakers of English (two males and two females) participated in the production task in order to provide native speaker base-line data. The native speakers of English were Canadians with an average of 6.3 years of living in Korea at the time of recording. All the participants were paid for providing their production data.

2. Materials

In order to collect production data, 24 nonce words were selected. The words included four sibilants of /s, ʃ, z, ʒ/ in two different positions (i.e., intervocalic and word-final) and in the contexts of three different vowels (i.e., /a, i, u/) respectively. Sibilants in word-initial positions were not included in the present study, since [ʒ] does not appear in the particular position in English. Table 1 illustrates the stimuli used in our experiment.

[1] It is possible that males and females have shown different acoustic results according to their gender; since the participants in the present study were counterbalanced according to gender, it was presumed that the gender effects would be neutralized. A comparison based on acoustic results across gender is open for a future study.

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TABLE 1
Stimuli for the Production Experiment

	[s]	[ʃ]	[z]	[ʒ]
Intervocalic	asa	aʃa	aza	aʒa
	isi	iʃi	izi	iʒi
	usu	uʃu	uzu	uʒu
Word-final	as	aʃ	az	aʒ
	is	iʃ	iz	iʒ
	us	uʃ	uz	uʒ

The nonce words were presented in the IPA systems as shown in the table above. For those participants who were not trained to use the IPA systems, a training session was provided: the participants were asked to read a set of English words transcribed in the IPA systems for the purpose of familiarization. For VCV disyllabic words, the participants were instructed to place a primary stress on the initial syllable.

3. Procedure

During the entire procedure, participants were instructed to read each word at a rate as natural as possible. The order of words was kept identical across participants. Additionally, whenever these participants expressed difficulty in reading the IPA system, they were allowed to go back to look at the training session material (i.e., words presented in the IPA system). Recordings were completed in a quiet room with a head-mounted microphone (Audio-Technica M8541) and TASCAM HD-P2 recorder at a setting of 44100 Hz and 16 bits. Three recordings were completed overall for each participant.

Of the three recordings, only the last one was used in the analysis. As a result, 336 stimuli were obtained, among which L2 learners produced 240 (4 segments X 2 positions X 3 vowel types X 10 participants) and native speakers 96 (4 segments X 2 positions X 3 vowel types X 4 participants). One stimulus (i.e., uʒu) produced by one Korean L2 learner was excluded from the analysis since he failed to produce a second vowel. Thus, a total of 335 stimuli were included in the final analysis.

With the data, acoustic measurements were taken in Praat in the following ways. First, for each token, the ratios of sibilants and preceding vowels in each stimuli were measured. Second, fundamental frequency (F0), F1, F2 and F3 were measured at the vowel-sibilant boundaries. Third, centroid frequency (CF) and peak amplitude frequency (PAF) were measured. The centroid of the fricative noise is defined as the center of gravity of a defined part of the spectrum, each frequency being weighted according to its amplitude (Cho, Jun

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& Ladefoged, 2002; Forrest, Weismer, Milenkovic & Dougall, 1988; Jones & Munhall, 2003). PAF refers to the frequency of the spectral peak with the highest amplitude (Chang, Haynes, Rhodes & Yao, 2009). CF and PAF were measured around the midpoint of the frication noise by using FFT spectra in the frequency range from 500 to 10,000 Hz and a 25 ms window. Fourth, the ratio of frication noise in a sibilant was measured. The ratio of '1' refers to the frication noise throughout the duration of the entire sibilant. The ratio between '0' and '1' indicates the frication noise appearing only during a portion of the sibilant. This refers to the mispronunciation of sibilants as affricates. Additionally, for VCV words, F0, F1, F2 and F3 were measured at the sibilant-vowel boundaries. Due to the additional measurement at the intervocalic positions, separate statistical analyses were conducted in each position. Acoustic differences of sibilant types according to vowel types were not the focus of the present study.

III. RESULTS

To analyze the production experiment data, a series of MANOVAs were performed in each position (i.e., final and intervocalic) in each participant group (i.e., Korean L2 learners and native English speakers) for the sibilant types concerned (i.e., [s] vs. [ʃ] and [z] vs. [ʒ]). Among the results of acoustic measurements, our analysis will focus on statistically significant ones. The analysis will also include cases where similar or opposite trends were observed between L2 learners and native speakers.

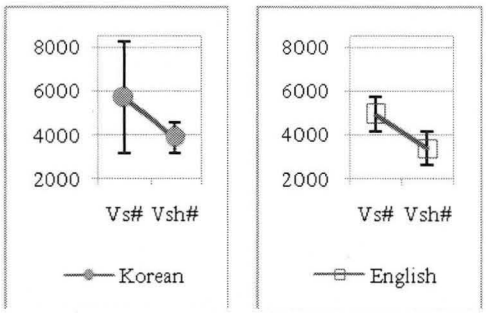
1. Final Position

Both Korean L2 learners and native speakers of English used CF and PAF as important factors in differentiating word-final [s] and [ʃ]. As illustrated in Figure 1, both Korean L2 learners and English native speakers showed higher CFs with [s] than with [ʃ] ($F = 14.810$, $p<.05$; $F = 23.247$, $p<.05$). The average CFs of Korean L2 learners of English were at 5706.4 Hz with [s] and 3862.1 Hz with [ʃ]; English native speakers exhibited CFs at 4934.6 Hz with [s] and 3370.0 Hz with [ʃ]. Although the trends were similar in both groups, a standard deviation of [s] with Koreans (SD = 2531.3) was far greater than with native speakers (SD = 811.8).

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FIGURE 1

Average CF of [s] and [ʃ] in Final Position, Korean and English Speakers

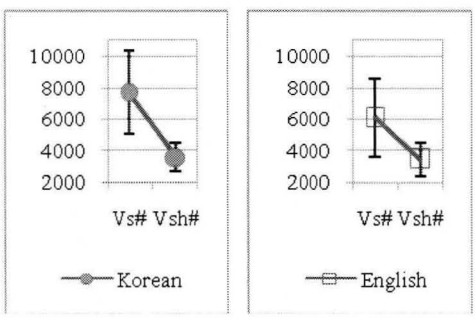


Note: sh = ʃ

For the PAF, [s] was higher than [ʃ] with Korean L2 learners of English ($F = 66.542$, $p<.05$) and also with English native speakers ($F = 11.440$, $p<.05$). The average PAFs of Korean L2 learners of English were at 7719.0 Hz with [s] and 3565.5 Hz with [ʃ]; English native speakers exhibited PAFs at 6067.3 Hz with [s] and 3414.5 Hz with [ʃ]. Figure 2 illustrates the finding.

FIGURE 2

Average PAF of [s] and [ʃ] in Final Position, Korean and English Speakers



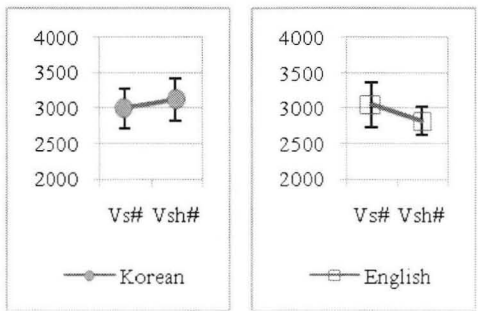
Note: sh = ʃ

For the F3 at the vowel-sibilant boundary (V1_F3), Korean learners of English did not exhibit a significant difference between [s] and [ʃ] ($F = 2.819$, n.s.), whereas English native speakers showed a significant difference ($F = 4.723$, $p<.05$). The two groups exhibited an opposite trend, as illustrated by Figure 3. Average F3 of Korean group was higher with [ʃ] at 3121.5 Hz than with [s] at 2993.7 Hz, whereas that of native speakers was higher with [s] at 3054.2 Hz than with [ʃ] at 2821.5.

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FIGURE 3

Average V1_F3 of [s] and [ʃ] in Final Position, Korean and English Speakers



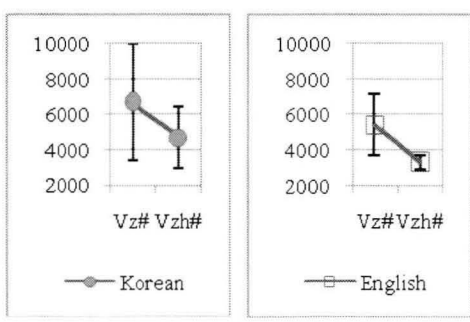
Note: sh = ʃ

For the F2 at the vowel-sibilant boundary (V1_F2), Korean learners of English showed a significant difference between [s] and [ʃ] ($F = 19.280$, $p<.05$). Native speakers of English did not show a significant difference ($F = .859$, n.s.); however, the trend was similar in that their F2s were higher with [ʃ] than with [s].

With word-final [z] and [ʒ], both Korean L2 learners of English and native speakers of English used PAF as a significant acoustic cue ($F = 8.636$, $p<.05$ for Korean L2 learners; $F=16.826$, $p<.05$ for native speakers). In both groups, PAFs of [z] were higher than those of [ʒ] (for Koreans, 6692.4 Hz with [z] and 4697.1 Hz with [ʒ]; for native speakers of English, 5418.9 Hz with [z] and 3310.3 Hz with [ʒ]). Standard deviations of Korean learners were greater at 3281.1 with [z] and 1750.5 with [ʒ], whereas those of native English speakers were lower at 1735.3 with [z] and 399.4 with [ʒ]. Figure 4 shows the finding.

FIGURE 4

Average PAFs of [z] and [ʒ] in Final Position, Korean and English Speakers



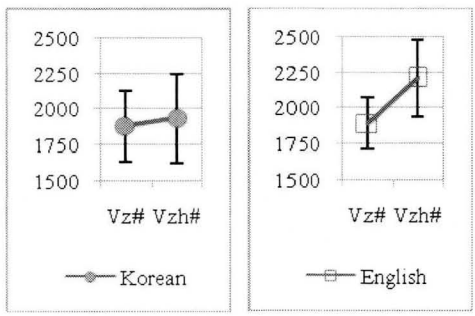
Note: zh = ʒ

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F2 at the vowel-sibilant boundary (V1_F2) was a significant acoustic factor differentiating [z] and [ʒ] with native speakers of English ($F = 11.322$, $p<.05$). As is illustrated in Figure 5, V1_F2 of native speakers of English with [ʒ] was significantly higher at 2212.2 than with [z] at 1893.6. Korean L2 learners did not show a significant difference ($F = .577$, n.s.) with the same cue.

FIGURE 5

Average V1_F2s of [z] and [ʒ] in Final Position, Korean and English Speakers

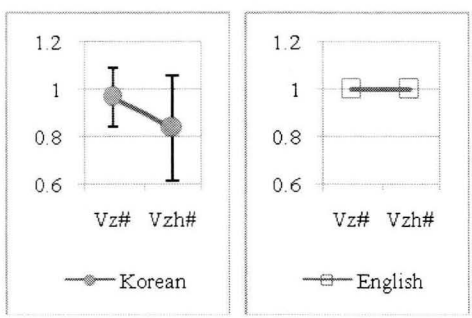


Note: zh = ʒ

Ratio frication was a significant acoustic cue for Korean L2 learners in discriminating [z] and [ʒ] ($F = 7.806$, $p<.05$). Ratio frication of [z] was close to 1 (.97), whereas that of [ʒ] was lower at .84. As is shown in Figure 6, native speakers of English did not show any difference in the cue.

FIGURE 6

Average Ratio Frication of [z] and [ʒ] in Final Position, Korean and English Speakers



Note: zh = ʒ

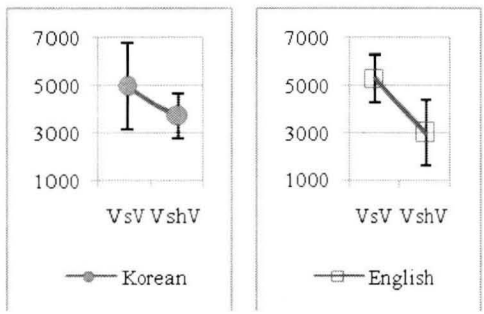
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2. Intervocalic Position

As with the final position, both Korean L2 learners and native speakers of English used CF and PAF as important factors in differentiating intervocalic [s] and [ʃ]. Korean L2 learners exhibited a higher CF of [s] at 4954.5 Hz than that of [ʃ] at 3703.0 Hz ($F = 11.207$, $p<.05$); Native English speakers also showed a higher CF of [s] at 5303.8 Hz than that of [ʃ] at 2996.2 Hz ($F = 21.920$, $p<.05$). Figure 7 illustrates the finding.

FIGURE 7

Average CF of [s] and [ʃ] in Intervocalic Position, Korean and English Speakers

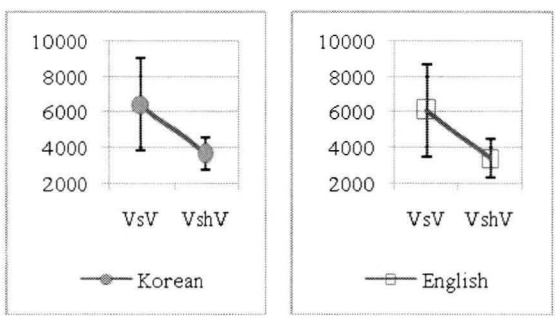


Note: sh = ʃ

PAFs were significantly higher with [s] than with [ʃ] across groups. Korean L2 learners exhibited a higher PAF of [s] at 6440.9 Hz than that of [ʃ] at 3637.7 Hz ($F = 30.633$, $p<.05$); Native English speakers also showed a higher CF of [s] at 6118.2 Hz than that of [ʃ] at 3411.2 Hz ($F = 11.091$, $p<.05$). Figure 8 illustrates the finding.

FIGURE 8

Average PAF of [s] and [ʃ] in Intervocalic Position, Korean and English Speakers



Note: sh = ʃ

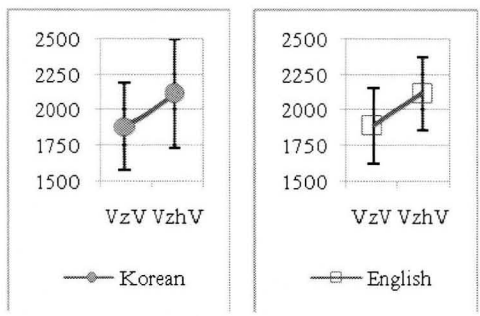
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Additionally, V1_F2 was found to be a significant acoustic cue for the production of [s] (1890.5 Hz) and [ʃ] (2145.7 Hz) with Korean L2 learners of English ($F = 6.059$, $p<.05$). Unlike these learners, V1_F2 was not a significant acoustic cue for native English speakers ([s] = 1816.1 Hz, [ʃ] = 1966.0 Hz), although both groups showed a similar trend.

With intervocalic [z] and [ʒ], both Korean and English speakers exhibited significantly higher F2s at the sibilant-vowel boundary (V2_F2). Korean speakers' V2_F2 with [z] was lower at 1884.7 Hz than that of [ʒ] at 2111.7 Hz ($F = 6.336$, $p<.05$). Native English speakers' V2_F2 with [z] was also lower at 1890.8 Hz than that of [ʒ] at 2116.3 Hz ($F = 4.413$, $p<.05$). The finding is illustrated in Figure 9.

FIGURE 9

Average V2_F2 of [z] and [ʒ] in Intervocalic Position, Korean and English Speakers

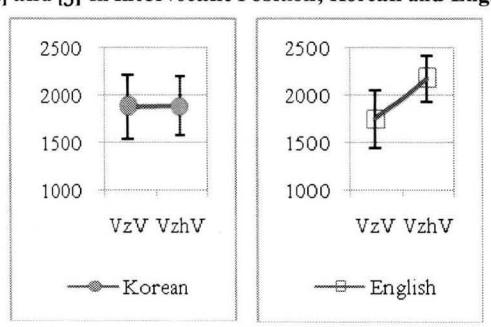


Note: zh = ʒ

Native speakers of English exhibited sigificantly higher V1_F2 with [ʒ] at 2178.5 Hz than with [z] at 1749.0 Hz ($F = 14.649$, $p<.05$). On the other hand, Korean learners of English showed no significant differences between [z] and [ʒ] ($F = .058$, n.s.) as illustrated by Figure 10.

FIGURE 10

Average V1_F2 of [z] and [ʒ] in Intervocalic Position, Korean and English Speakers



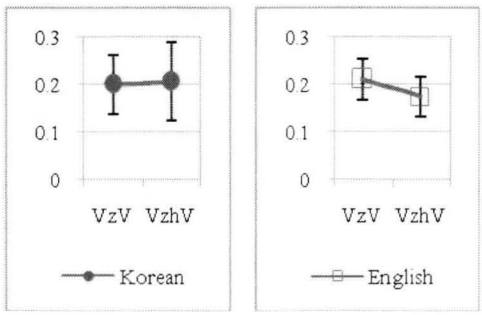
Note: zh = ʒ

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Native English speakers' ratio of sibilants was significantly higher with [z] at .21 than [ʒ] at .17 ($F = 4.418$, $p<.05$). Korean L2 learners of English did not differ in terms of ratio sibilants ($F = .612$, n.s.) of [z] and [ʒ]. The finding is illustrated in Figure 11.

FIGURE 11

Average Ratio of Sibilants of [z] and [ʒ] in Intervocalic Position, Korean and English Speakers

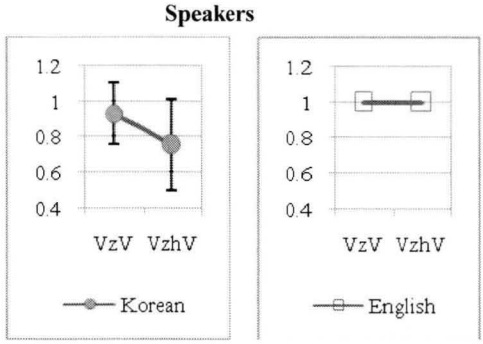


Note: zh = ʒ

As with ratio frication within sibilants, Korean L2 learners of English exhibited significantly higher values with [z] (.93) than with [ʒ] (.75) ($F = 10.853$, $p<.05$). Native speakers of English group exhibited identical ratio frication of 1 in both [z] and [ʒ]. The finding is illustrated in Figure 12.

FIGURE 12

Average Ratio of Frication of [z] and [ʒ] in Intervocalic Position, Korean and English Speakers



Note: zh = ʒ

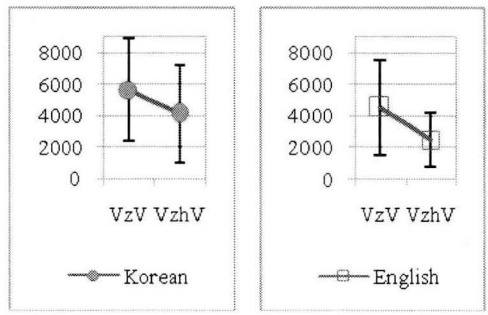
A factor marginally significant for native speakers of English was PAF, with [z] at 4534.0 Hz and with [ʒ] at 2485.1 Hz ($F = 4.191$, $p<.053$). Although Korean L2 learners did not show a significant difference, they showed a similar value ($F = 3.209$, n.s.). As is

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illustrated in Figure 13, the overall values of Koreans were higher than that of native speakers of English.

FIGURE 13

Average PAF of [z] and [ʒ] in Intervocalic Position, Korean and English Speakers

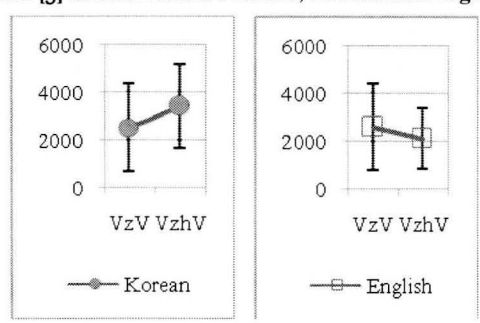


Note: zh = ʒ

For Korean L2 learners of English, CF was a marginally significant factor ($F = 3.955$, $p<.052$). With [z], the value was at 2511.0 Hz whereas it was 3417.3 Hz with [ʒ]. Native speakers of English did not show any significant difference ($F = .583$, n.s.). The trends in two groups were opposite. This is illustrated in Figure 14.

FIGURE 14

Average CF of [z] and [ʒ] in Intervocalic Position, Korean and English Speakers



Note: zh = ʒ

3. Summary of Results

The following Table 2 summarizes findings described in the previous section. It describes significantly different acoustic cues for each pair of sibilants within each group.

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TABLE 2

Summary of Results

	Korean		English	
	[s] vs. [ʃ]	[z] vs. [ʒ]	[s] vs. [ʃ]	[z] vs. [ʒ]
Final Position	V1_F2	Ratio_frication	V1_F3	V1_F2
	CF	PAF	CF	PAF
	PAF		PAF	
Intervocalic Position	V1_F2	Ratio_frication	CF	V1_F2
	CF	V2_F2	PAF	PAF
	PAF	CF		V2_F2
				Ratio_sibilant

IV. DISCUSSION AND CONCLUSION

Both Korean L2 learners of English and native speakers of English commonly employed CF and PAF as determining acoustic cues in producing final and intervocalic [s] and [ʃ]. The results indicated that [s] was consistently higher than [ʃ] in terms of both CF and PAF. As with CF of [s] in final position, the Korean L2 learners of English attested a standard deviation approximately three times that of native English speakers. Since CF is a cue related to place of articulation, it suggests that learners exhibited high intersubject variation by producing sibilants in varied regions of the oral cavity. Higher PAFs with alveolar fricatives have been attested in many previous studies (Behrens & Blumstein, 1988; Chang et al., 2009; Heinz & Stevens, 1961; Hughes & Halle, 1956; Klatt, 1978; Ladefoged, 2005). As was pointed out in Seo and Lim (2009), Stevens (1971) and Fant (1960) attributes lower PAF for palato-alveolar fricatives to the length of the front cavity before the constriction and to the occurrence of lip protrusion. According to Stevens and Fant, palato-alveolar fricatives have the longer front cavity than alveolar fricatives, resulting in lower PAF. Additionally, palato-alveolar fricatives accompany lip protrusion which also leads to lower PAF.

Higher CFs with alveolar fricatives than with palato-alveolar fricatives have been reported in a substantial number of previous studies (Chang et al., 2009; Cho et al., 2002; Kang et al., 2009; Li et al., 2007; Nittrouer et al., 1989). CF, which refers to fricative frequency center of gravity, negatively correlates with the length of the front resonating cavity. Thus, alveolar fricatives have higher CFs than palato-alveolar fricatives since the former are produced with a more anterior constriction than the latter.

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Despite the similarities of two groups attested by CF and PAF, a significant difference was found between two groups in terms of V1_F3. The cue of V1_F3 was significant only for the native speakers of English, with [s] showing higher F3 at the vowel-sibilant boundary than [ʃ]. Korean L2 learners of English did not show a significant difference between [s] and [ʃ]. This suggests that Korean L2 learners did not add lip rounding when pronouncing [ʃ]. This suggests L1 influence, as Korean allophonic variant [ʃ] of /s/ is reported to be produced without lip rounding and protrusion (Chun, 1982). As is widely known, English palato-alveolar fricatives are produced with lip rounding, thus yielding lower F3 (Ladefoged, 2006).

As with final [z] and [ʒ], both Korean L2 learners and native speakers of English showed significantly different PAFs: higher with [z] than with [ʒ]. Since both [ʃ] and [ʒ] are palato-alveolars, the explanation of lip rounding and longer front cavity before the constriction for [ʃ] is also applicable for [ʒ]. As was discussed above with CF of [s] in final position, Korean L2 learners showed much higher standard deviations for PAFs of [z] and [ʒ] than native speakers. Again, this high individual variation is a characteristic often observed among L2 speakers.

In the intervocalic position, significantly different V2_F2s were observed between [z] and [ʒ] with both groups: higher with [ʒ] than with [z]. F2 at the sibilant-vowel or vowel-sibilant boundaries is related to the place of articulation of consonants, as has been reported by many studies (Jongman, Wayland, & Wong, 2000; McGowan & Nittrouer, 1988; Nittrouer, 2002; Nittrouer, Studdert-Kennedy & McGowan, 1989). These studies have shown higher F2 with palato-alveolar fricatives than with alveolar fricatives.

Considering that F2 at the vowel-sibilant boundary is also influenced by the place of articulation of consonants as mentioned above, higher V1_F2 with [ʒ] than with [z] was expected. The pattern was observed only with native speakers of English unlike V2_F2. With final and intervocalic [z] and [ʒ], native speakers of English exhibited significantly different V1_F2 (i.e. F2 at the vowel-sibilant boundary) while Korean L2 learners of English did not.

Ratio frication with [z] and [ʒ] was another important difference between Korean L2 learners of English and native speakers of English. Native speakers' ratio frication was consistent across [z] and [ʒ], with a value of 1. This indicates that these speakers produced both segments as fricatives, showing frication throughout the duration of segments. Korean L2 learners of English, however, did not show this consistency. With [z], the ratio of frication was close to 1 at .93. Their ratio of frication with [ʒ] was significantly lower at .75. This indicates that they only produced frication for only a portion of the duration of segments, by pronouncing them as affricates. Shorter frication was observed with [ʒ] than with [z], suggesting that Korean L2 learners produced [ʒ] as affricates more frequently than [z]. A similar trend was observed with our previous study (Seo & Lim, 2009) of

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production of minimal pairs including [z] and [ʒ]. Among 80 tokens of words with [z] and [ʒ], affrication was attested in 31.3% of the data. In addition, unlike native speakers of English, Korean L2 learners of English showed higher CF with [ʒ] than with [z] in intervocalic position.

Overall, Korean L2 learners of English experienced more difficulty with [z] and [ʒ] than with [s] and [ʃ]. With [s] and [ʃ], Korean L2 learners employed CF and PAF in both intervocalic and final positions as native speakers of English did. We could also find differences in that Koreans employed V1_F2 in both positions and native speakers of English did not. However, as mentioned in the results section, native speakers group showed a similar trend with no significant difference between [s] and [ʃ].

With [z] and [ʒ], PAF was commonly attested only in the final positions of Koreans and native speakers. V2_F2 was another common cue in intervocalic positions of both groups. However, a marked difference was observed in the use of ratio frication by Korean L2 learners of English with [z] and [ʒ]. This is a trend which does not exist in the production of native speakers of English at all, suggesting that [z] and [ʒ] were more difficult for Korean L2 learners of English than [s] and [ʃ].

This may be due to the influence of L1 of Korean L2 learners of English. In Korean, [s] and [ʃ] are allophonic variants of /s/, which is realized as [ʃ] before the high front vowel /i/ or the palatal glide /j/ (Sohn, 1999). In contrast, [z] and [ʒ] are sounds that do not occur in Korean at all. According to our experiment, even in cases when two sounds are not contrastive phonemes in L1, learners still may find it easier to acquire two sounds in allophonic relations than in cases when the particular sounds do not occur in L1.

The results of this study, therefore, are not in accordance with the predictions made by Flege (1995; 1999). Korean L2 learners were better with their production of [s] and [ʃ], which are phonetically more similar to Korean correspondents, than with that of [z] and [ʒ]. Predictions made by Brown (2000) were also not borne out. Unlike her prediction that [s] and [ʃ] will be just as difficult as [z] and [ʒ], [s] and [ʃ] created less difficulty to Korean L2 learners of English.

The results of the present study call for more empirical data that measure similarities between L1 and L2 sounds. For example, a detailed acoustic measurement of phonetic distance is needed to ascertain similarities and differences between English [z, ʒ] and Korean [tɕ] and also between English [s, ʃ] and Korean [s, s'].

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Examples in: English
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