The influence of L2 experience on the perception of nonnative phonemic contrasts*

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Lee, Shinsook. 2010. The influence of L2 experience on the perception of nonnative phonemic contrasts. *Studies in Phonetics, Phonology and Morphology* 16.1. 123-145. This study investigated early Korean L2/EFL learners' perception of English fricative sounds in order to find out whether learners' different L2 experience influenced the way fricatives were perceived. For this purpose, three groups of children with different L2 experience took part in the study: 20 Korean EFL students, 21 bilingual returnees currently enrolled in an English-immersion program and 19 English-dominant bilinguals residing in the U.S. Their mean age was 9. They took a discrimination test with 48 English nonce words containing voiceless fricatives with four places of articulation (labiodental /f/, interdental /ɵ/, alveolar /s/, alveopalatal /š/) before the front vowel /i/ and back vowels /ɔ/ and /a/ (e.g., identical pairs: *findert-findert, farbin-farbin;* non-identical pairs: *findert-thindert*, *farbin-tharbin*). The results showed that perception of fricative sounds was affected by participants' different English-language experience. This is because EFL students outperformed Returnees or English-dominant bilinguals on discriminating non-identical stimuli but the latter groups were almost native-like in discriminating identical stimuli. The results also revealed that overall participants with more L2 experience surpassed those with less L2 experience in discrimination and that identical stimuli were better perceived than non-identical ones (84.6% vs. 62.4%). Moreover, Returnees and English-dominant bilinguals had much difficulty distinguishing the labiodental /f/ from the interdental /ɵ/ and also the interdental /ɵ/ from the alveolar /s/. In contrast, Korean EFL students had trouble in perceiving identical alveopalatal /š/ vs. alveopalatal /š/ pairs (e.g., *sholtem-sholtem*), even though they were better than Returnees and English-dominant bilinguals in discriminating between the labiodental /f/ and the interdental /ɵ/ and also between the interdental /ɵ/ and the alveolar /s/. Accordingly, the results are consistent with the hypothesis that perception of nonnative phonemic contrasts is influenced by learners' L1/L2 experience. Further, there was a back vowel advantage, as some of the target sounds were discriminated better before back vowels than before front vowels. In addition, implications of the results are discussed in terms of L2 speech perception models (Flege 1995, Best 1995, Best and Tyler 2007). **(Korea University)**

Key words: nonnative sounds, early bilinguals, EFL children, perception, L2 experience, stimulus type, place of articulation, vowel effects

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1. Introduction

It has been well-established that native language (L1) influences the way sounds in a second language (L2) or a foreign language (FL) are perceived (Best 1995, Flege 1995). In addition to L1 influence, other factors such as age of the onset of L2/FL acquisition, amount of L2 use, length of exposure to L2 input, target sounds' place of articulation and neighboring sounds feature in the perception of nonnative speech sounds (Mack 2003, Sundara and Polka 2008).

As for L1 interference, it is widely observed that adult L2/FL learners have difficulty perceiving nonnative phonemic/phonetic contrasts. For example, Japanese and Korean learners of English have difficulty perceiving the English /r/ and /l/ contrast, as both Japanese and Korean do not have the sound contrast (Ingram and Park 1998). Flege (1995) also reported that L1 Italian L2 English learners often misperceived the English voiced interdental fricative /ð/ as the voiced stop /d/ in word-initial position, since Italian does not contain interdental fricatives. Similarly, Guion et al. (2000a) found that native Japanese listeners heard the English voiceless interdental fricative /ɵ/ as the Japanese /s/ or /ɸ/ due to the absence of the sound in Japanese. Joh and Lee (2001) also examined Korean EFL learners' perception of English fricative sounds /s/, /ɵ/, and /š/ in word-initial position and reported that the interdental sound /ɵ/ presented great difficulty to them.

In addition to L1 interference, age of acquisition is known to be important in L2/FL acquisition. Specifically, research found that early L2 learners acquire native accent of L2, whereas adult L2 learners show their L1 accent even after many years of L2 experience. For example, Oyama (1976) reported that age of arrival (AOA) was closely related to foreign accent in the speech of 60 Italian immigrants to the United States. Similarly, Mack (2003) reported that only early Korean-English bilinguals who had been exposed to English before age five were able to perceive the contrast between the vowel pair /i/ and /ɪ/. As for L2 experience, studies showed that length of exposure to the L2/FL is closely related to foreign accent. That is, the longer exposed to the L2, the less foreign accent. Likewise, amount of L2 use pertains to foreign accent, as learners with more L2 and less L1 use sound less foreign accented (Guion et al. 2000b). Similarly, Strange and Shafer (2008) claimed that the patterns of perceptual difficulty were related to L2 experience, since experienced L2 learners could establish separate L2 categories, as opposed to inexperienced L2 learners. However, Flege (1995) found that even experienced L1 Spanish L2 English learners showed perceptual problems in discriminating several nonnative vowel contrasts like /ɛ/ vs. /æ/ and /a/ vs. /ʌ/.

Moreover, Gottfried (1984) reported that naïve English listeners had more difficulty with the French front vs. back rounded vowel pair (/y/ vs.

/u/) in alveolars than in labials, but they had more difficulty with the front unrounded and rounded vowel pair (/i/ vs. /y/) in labials than in alveolars. Gay (1970) also showed that vowel contexts could affect consonant perception, similar to the effects of consonantal contexts on vowel perception.

However, the interaction among the factors above in the perception of nonnative phonemic contrasts by early language learners has not been much investigated. Thus, this study examines early Korean-English bilinguals' and early Korean EFL learners' perception of English fricative sounds in two vowel contexts. More specifically, three groups of children with different L2 experience participated in the study: 20 Korean children who learned English only in classroom settings, 21 bilingual returnees from English speaking countries currently enrolled in an English-immersion program and 19 English-dominant bilinguals residing in an English speaking country. They were 9 years old on average. They were presented with English nonce words. The nonce words all contained word-initial voiceless fricatives with four places of articulation (labiodental /f/, interdental /ɵ/, alveolar /s/, alveopalatal /š/) and the fricatives occurred before the high front vowel /i/ and back vowels /ɔ/ and /a/ (e.g., *findert, thindert, siknet, shipkin*; *farbin, tharbin, soltem, sholtem*). This study specifically examined these fricatives which differ in terms of place of articulation, since Korean has only two alveolar fricative sounds, the lax /s/ and the tense /s'/, and the alveopalatal fricative sound [š] occurs as an allophone of /s/ before /i/ in Korean. Thus, Korean EFL learners often palatalize the /s/ sound in words like *sip*, which may cause some difficulty in the perceptual distinction between /s/ and /š/ before /i/. Further, first language learners who acquire English as their mother tongue often confuse /f/ with /ɵ/, while Korean EFL learners have difficulty distinguishing between /s/ and /ɵ/. Consequently, it is expected that learners may show different error patterns in perceiving English fricative sounds depending on their L1/L2 experience.

In particular, the present study explores the following questions: 1. Does learners' different L2 experience influence perception of L2/FL sounds?; 2. If so, do the learners show different error patterns depending on their L2 experience?; 3. Do target consonants' places of articulation and the following vowels affect the way target sounds are perceived? In order to investigate the research questions, total 48 stimuli were presented in an AX discrimination task.

The paper is structured as follows. Section 2 reviews factors pertaining to nonnative speech perception, especially L1 interference, age of L2/FL acquisition, length of exposure to L2/FL input and/or amount of L2/L1 use. It also examines the influence of target sounds' places of articulation and the following vowels on perceiving nonnative sounds. Section 3 reports on the experiments run on the perception of English fricative sounds. Section 4 discusses the results of the experiments and Section 5 discusses general

findings and considers implications of the present study for L2 speech perception.

2. Factors in the perception of nonnative sounds

2.1 Native language interference

Studies on infant speech perception reported that 10-to 12-month-old infants showed a decline in perception of some nonnative contrasts, even though younger infants were able to contrast nonnative sounds (Werker et al. 1981, Werker and Tees 1983). For instance, according to Werker and colleagues, 6-month-old English infants were able to differentiate the Hindi retroflex vs. dental stops, whereas 11-to-12-month olds failed to distinguish the same place contrasts. Follow-up studies reported that older English children (4-year-olds, 8-year olds and 12-year olds) also failed to differentiate the Hindi stop place contrast (Strange and Shafer 2008). Other studies showed that sensitivity to nonnative sounds is reduced between 6 and 12 months of age. As opposed to nonnative sound contrasts, even older infants did not exhibit insensitivity to native phonemic contrasts. Thus, infant research suggested that L1 influences are evident during a child's second half-year. For example, Werker and Curtin (2005) contended that younger infants show language-general patterns of sound perception, while older infants exhibit language-specific patterns. Best et al. (2001:791) also suggested that infants first detect only nonlinguistic information in speech and then recognize the way phonetic allophones fit into language-specific phonetic classes and finally discover the contrastive functions of phonetic classes in their L1.

The facts above indicate that the L1 phonological system is established early in life and it may function as a filter, which affects the way nonnative sounds are perceived. According to Flege's Speech Learning Model (henceforth, SLM, 1995), L2 learners tend to perceptually equate positional variants in the L2 to the closest sounds in the L1 in terms of positionally defined acoustic/phonetic cues. Similarly, Best's Perceptual Assimilation Model (henceforth, PAM, 1995) maintained that naïve listeners have a tendency to perceptually assimilate a nonnative sound to the closest native sound in terms of articulatory gestures. For example, Schmidt (1996), replicating Kim's (1972) earlier study on the perceptual category mapping between English and Korean sounds, reported that English /f/ was predominantly labeled as the Korean aspirated bilabial stop /p^h/, while English /ɵ/ was mostly mapped to the Korean tense alveolar fricative /s'/ or stop /t'/ and further to the aspirated bilabial stop /p^h/. In a follow-up study, Cho and Lee (2007) showed that English fricatives which do not contrast in Korean were more diversely mapped to Korean categories and the mapping patterns were also influenced by prosodic positions in which the target sounds occurred. Similarly, Japanese learners

of English showed perceptual difficulties in perceiving English fricative sounds. For instance, Lambacher et al. (1997) reported that Japanese listeners had great difficulty distinguishing between /ɵ/ and /s/. According to them, 28% of Japanese listeners misidentified /ɵ/ as /s/ and 25% of them also misjudged /s/ as /ɵ/. Further, 13% of them chose /f/ for /ɵ/.

2.2 Age of L2 acquisition

It has been noted that phonology is influenced by the learner's age of the onset of L2/FL acquisition more than any other area of language. Namely, early L2 learners are observed to produce more native-like sounds than late L2 learners, especially compared to adult L2 learners. Early L2 learners are defined as learning an L2 before the age of 8, whereas late L2 learners are learning an L2 over age 16 (Ioup 2008). Yet, Long (1990) suggested that age 6 should be the cut-off point to acquire native-like accent. For example, as mentioned earlier, Oyama (1976) reported that Italian immigrants to the United States who started learning English before age 10 were judged to be more like natives by native English speakers. She further reported that other factors such as length of stay in the L2 settings and learners' motivation to learn English were not correlated with their performance. Similarly, according to Flege et al. (1999), Italian immigrants to Canada showed age effects in that only some earliest arriving immigrants were able to produce English vowel pairs without their L1 influence.

Moreover, learners' nonnative like L2 production is assumed to be closely related to the learners' poor perception of the L2 input (Flege 1995).[1] Mack (2003) investigated perception of the English vowel pair /i-ɪ/ by Korean-English bilinguals whose age of arrival in the U.S. varied: 0-4, 5-9, 10-14, and over 15. At the time of testing, all of the participants were fluent bilingual college-students and they discriminated a synthesized continuum of the English vowel pair /i-ɪ/. According to Mack, only those who had been exposed to English before age 5 were able to perceive the boundary between /i/ and /ɪ/ like native listeners. She further reported that length of exposure to English or level of Korean proficiency was not strongly correlated with the participants' performance. Likewise, Pallier et al. (1997) examined perception of a Catalan vowel contrast by two groups of Spanish-Catalan bilinguals. One group learned Catalan at ages 5 to 6 and the other had been exposed to both Spanish and Catalan from birth. The results showed that only participants who had been exposed to Catalan from birth perceived the Catalan vowel contrast.

In similar vein, MacKay et al. (2001) investigated early and late Italian-English bilinguals' perception of short-lag English voiced stops /b, d, g/. The bilinguals differed in terms of their age of arrival and amount of L1

[1] Lenneberg (1967) contended that L2 learners cannot perceive or produce new sounds because of the brain maturation process.

use. According to them, the late bilinguals (mean AOA: 20 years) were more strongly influenced by their L1 than the early bilinguals (mean AOA: 8 years) in perceiving English stops. MacKay et al. attributed this to differences in the English input quantity and quality that the bilinguals had received. Namely, the early bilinguals had been exposed to more authentic L2 input than the late bilinguals and thus the former were able to perceive English stops in a more native-like manner.

2.3 L2 experience and sound context

Besides the L1 phonological system and the age of L2 acquisition, other factors such as amount of L2 use and sound context are shown to be important in accounting for L2 phonological acquisition. As for L2 experience, Best and Strange (1992) investigated Japanese listeners' discrimination of English /w/-/r/ and /r/-/l/ pairs. They found that Japanese listeners showed higher rates of accuracy in discriminating English /w/-/r/ than /r/-/l/. They also reported that listeners who had more English-language experience contrasted the two pairs more like native English listeners compared to those who had less English-language experience.

However, a rather different picture was obtained concerning Japanese listeners' discrimination of English contrasts. According to Guion et al. (2000a), Japanese listeners with more English experience gained higher discrimination scores than those with less English experience for English /v/-/b/ and /r/-/w/ pairs, but not for English /r/-/l/ and /s/-/ɵ/ pairs. Further, they found that English-Japanese phonemic contrasts /v/-/b/ and /r/-/ɾ/[2] showed benefits of language experience, while the English-Japanese contrasting pair /l/-/ɾ/ did not. Accordingly, Guion et al. argued that some English-English and English-Japanese sound contrasts showed more effects of language experience than others. Moreover, some of sound contrasts in L2/FL continually pose challenges to the learners even after several years of experience with the L2/FL (Strange and Shafer 2008).

Concerning the effect of sound context on speech perception, it is well-established that vowels are longer before voiced obstruents than before voiceless ones in English (Celce-Murcia et al. 1996/2006). For instance, the vowels /ɪ/ in *rib* and *pig* and [eɪ] in *graze* are longer than the same vowels in *rip*, *pick*, and *grace*, which is one of the most important cues in distinguishing the consonants in final position. Concerning the effect of vowel context on consonant perception, Gay (1970) used low-pass filtered 16 English consonants (/p, t, k, b, d, g, s, f, z, v, w, j, r, l, m, n/) followed by seven vowels (/i, ɛ, æ, ʌ, ɔ, a, u/) in CV context and asked English listeners to identify the consonants. According to Gay, the consonants /p, b, d, j, n/ displayed invariably lower scores when the following vowel was /i/, while other consonants /k, g, f, v, m/ exhibited multivowel effects, thus

[2] The Japanese liquid /ɾ/ is produced as an apico-alveolar tap (Guion et al. 2000a).

showing that vowel context can also affect the way consonants are perceived.

Based on the literature reviewed above, the paper seeks to answer the following questions: Whether English-language experience affects early learners' discrimination of English consonants?; Whether certain English consonants are more difficult for the learners to discriminate than others?; If so, whether a target consonant's place of articulation and its following vowel affect perception of the target sound?

3. Research design

3.1 Participants

Three groups of young children participated in the study: 20 Korean EFL children (hereafter, called EFL students), 21 bilingual returnees (hereafter, called Returnees), and 19 English-dominant bilinguals (hereafter, called ED bilinguals). Their mean age was 9. More specifically, EFL children were third-graders who learned English in a classroom setting and they were recruited from a public school located in Jukjeon, Kyonggi province. Returnees were recruited from a private international school located in Seoul and they enrolled in an English-immersion program. ED bilinguals were recruited from public schools in Austin, Texas, in the U. S. and they all enrolled in a Korean-language learning program offered by a local community center. The present study recruited three groups of children with different English-language experience in order to examine whether L2 experience affected the way fricative sounds were perceived. Participants' background information is provided in Table 1, which was obtained through interview before or after the main test.

Table 1. Participants' background information

Group	Mean age (years)	Mean initial age of exposure to English(years)	Mean length of learning English (years)
Korean EFL students	9.0	7.6	2.3
Bilingual returnees	9.8	4.1	5.8
English-dominant bilinguals	8.8	1.9	6.9

As given in Table 1, the mean age was around 9 years for EFL students, 9.8 years for Returnees and 8.8 years for ED bilinguals. Most of the EFL students were first exposed to English after the age of 7 or 8 and had about 2.3 year history of English learning at the time the experiment was conducted. The Returnees started learning English at the age of around 5 and had been learning English for 5.8 years. The ED bilinguals began to learn English before the age of 2 and had around 6.9 year history of English

learning on average. An ANOVA conducted on the mean comparisons between subject groups revealed that each group was significantly different from one another with respect to length of English learning as well as initial age of exposure to English (all $p<.05$), which suggests that each group had different English-language experience.

3.2 Stimuli

Twenty-four disyllabic English nonce words with a voiceless fricative onset were first constructed. The syllabic structure of the words was either CVC.CVC or CVC.CVCC stressed on the first syllable. Based on the twenty-four nonce words, two sets of stimuli were created: 24 identical pairs (e.g., *fiktom-fiktom*) and 24 non-identical ones (e.g., *fiktom-thiktom*). Thus, the total number of stimuli was 48. The target fricatives with four places of articulation ―labiodental /f/, interdental /ɵ/, alveolar /s/, and alveopalatal /š/―were presented in two vowel contexts, the front vowel /i/ and the back vowels /a/ and /ɔ/. As mentioned earlier, English contrasts the four places of articulation, whereas Korean contrasts only the lax and tense alveolar fricative sounds /s/ and /s'/. Moreover, in Korean, the alveopalatal fricative [š] occurs as an allophone of /s/ before the vowel /i/ and it is articulated relatively front (near alveolar), as opposed to the English /š/. Consequently, Korean learners of English often palatalize the alveolar /s/ before the vowel /i/, thus creating homophones in the production of words like *sip* (e.g., *sip* and *ship* as [šɪp]). They also have difficulty perceiving and producing the interdental fricative /ɵ/ and often replace it with the Korean lax/tense fricative or stop sounds (/s/, /s'/, /t/ or /t'/) depending on the following sound.[3] Moreover, native English children often confuse /f/ with /ɵ/ and tend to substitute /f/ for /ɵ/ due to their acoustic similarity. As Strevens (1960) reported, /f/ and /ɵ/ are very low in intensity and the location of spectral peaks for the two sounds is very similar, which leads to great difficulty in place distinction between the two sounds. As a result, the present study examined the four voiceless fricative sounds in two vowel contexts (i.e., front and back vowels) in order to investigate whether participants' different experience with the English language affects the perception of fricatives. Besides the overall mean rate of accuracy, the study examined whether participants showed effects of place of articulation and following vowels on perceiving the fricatives.

A male speaker of American English made audio recordings. He produced the target words in the carrier sentence of "Say the word _____" three times. Best examples were chosen from the three repetitions. The testing materials were made with Audacity and a SONY ECM-MS907

[3] Kim (1999), and Cho and Lee (2001) reported that Korean learners of English tensed the English alveolar fricative /s/ before a vowel.

microphone to a PC at 44.1 kHz at 16 bit in a sound-attenuating room. Sample stimuli are listed in the appendix.

3.3 Procedure

A discrimination task was administered using E-prime 2.0. The presentation order of the 48 stimulus items was randomized across participants. They sat at a computer in a sound-treated room and wore headphones. Participants listened to instructions for the task and finished 4 practice trials before the main task. At the end of the practice trials, participants were asked whether they had any questions on the task in order to make sure that they clearly understood the task. In particular, they were asked to press the corresponding key (i.e., same or different) as fast as possible on the keyboard after a stimulus presentation. Participants were given a maximum of 3 seconds to respond in each trial. The next trial began after a 2 second inter-trial interval. Before or after the test, participants completed a questionnaire on their language background information. EFL students took the test at their school, while Returnees at a private university in Seoul. ED bilinguals took the test at a public school or at a private home in Austin, Texas, in the U.S.

3.4 Analysis

Correct individual item reaction times that were over 3000ms were excluded from the final analysis, as in Wheeldon and Waksler (2003). This led to the exclusion of 2.81% from the total data for EFL students, 0.89% for Returnees, 4.16% for ED bilinguals in the subsequent analysis.

4. Results

The overall results were analyzed in terms of the following factors.

4.1 Effects of group and stimulus type

The overall results were analyzed in terms of stimulus type, as there were 24 identical (e.g., *findert-findert*) and non-identical (e.g., *findert-thindert*) stimuli each. A mixed ANOVA was conducted on mean accuracy and reaction times (henceforth, called RTs) with group (i.e., EFL students, Returnees, ED bilinguals) as a between-subjects factor and stimulus type (i.e., identity vs. non-identity) as a within-subjects factor. The results on mean accuracy showed that there was a main effect of group ($F(2,57)=5.574$, $p=.006$), as ED bilinguals performed slightly better than Returnees, who in turn performed much better than EFL students, as shown in Figure 1.

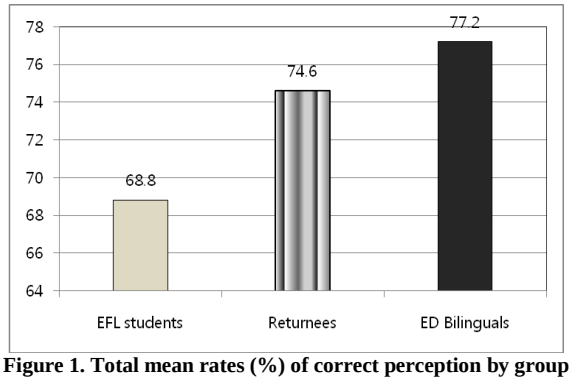

Figure 1. Total mean rates (%) of correct perception by group

Post hoc comparisons (Bonferroni) showed that the difference in correct percentages between EFL students and ED bilinguals was significant (p=.006). The effect of stimulus type was also significant (F(1,57)= 110.796, p<.0001) and there was a significant interaction between stimulus type and group (F(2,57)=28.481, p<.0001). This indicates that the way the stimuli were perceived was influenced by the participant group, even though identical stimuli were overall perceived much better than non-identical ones (84.6% vs. 62.4%). In particular, EFL students' mean rate of accuracy between identical and non-identical stimuli was almost the same, unlike that for other participant groups, as shown in Figure 2. Unexpectedly, EFL students outperformed not only Returnees but also ED bilinguals in perceiving non-identical stimuli, even though the opposite pattern was obtained with identical stimuli.

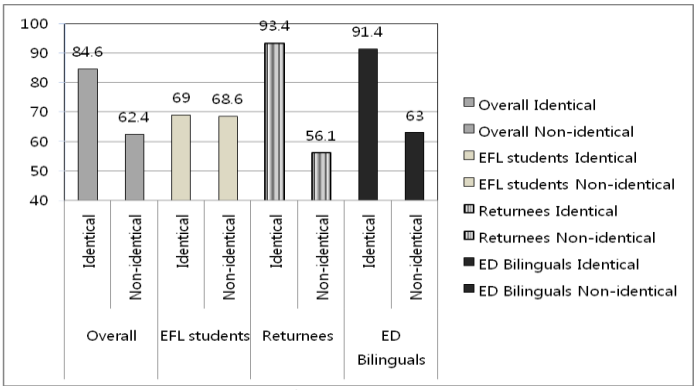

Figure 2. Correct percentages of identical vs. non-identical stimuli by group

The results on mean RTs revealed that there was no main effect of group (F(2,57)=.037, p>.05) and the interaction between stimulus type and group was not significant (F(2,57)=.039, p>.05). Yet, there was a significant

effect of stimulus type ($F(1,57)=7.928$, $p<.05$), as identical stimuli were responded much faster than non-identical ones (467ms vs. 525ms) across all the participant group.

4.2 Effects of place of articulation and vowels

The general results were also analyzed in terms of fricatives' places of articulation and the following vowels. As for the place of articulation, fricatives with four places of articulation were first subdivided into identical and non-identical stimuli. There were four places of articulation for identical stimuli: labiodentals (e.g., *fiktom-fiktom*), interdentals (e.g., *thiknet-thiknet*), alveolars (e.g., *siknet-siknet*), and alveopalatals (e.g., *shipkin-shipkin*). Yet, there were three places of articulation for non-identical stimuli. This is because labiodentals were matched with interdentals (e.g., *fiktom-thiktom*), interdentals with alveolars (e.g., *thiknet-siknet*), and alveolars with alveopalatals (e.g., *sipkin-shipkin*). Consequently, the effect of the place of articulation was calculated separately for identical and non-identical stimuli.

For identical stimuli, a mixed ANOVA was run on mean accuracy and RTs, with group as a between-subjects factor and place of articulation as a within-subjects factor. The results on mean accuracy revealed that the effect of group was significant ($F(2,57)=29.620$, $p<.0001$). But there was no main effect of place ($F(3,171)=1.289$, $p>.05$) and the interaction between place and group was not meaningful ($F(6,171)=.370$, $p>.05$). This is due to the fact that Returnees and ED bilinguals outperformed EFL students in perceiving identical stimuli regardless of place of articulation (EFL students: 68.6%, Returnees: 93.4%, ED bilinguals: 91.4%). However, the way fricatives were perceived seems to be affected by the participants' L2 experience, even though there was no significant interaction between place of articulation and group. Namely, EFL students perceived /s/ better than other places of articulation, while ED bilinguals perceived /s/ and /š/ better than /f/ or /ɵ/. Returnees showed the same pattern as ED bilinguals, even though the former performed slightly better than the latter, as shown in Figure 3. The results on RTs showed that there was no significant effect of group or place. The interaction between place and group was not significant, either (all $p>.05$).

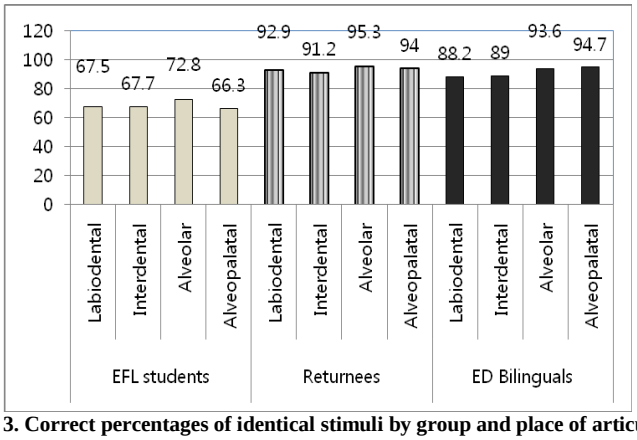

Figure 3. Correct percentages of identical stimuli by group and place of articulation

Now, let us consider the effect of place of articulation for non-identical stimuli. A mixed ANOVA run on mean accuracy showed a main effect of group ($F(2,57)=5.816$, $p<.05$), as EFL students outperformed ED bilinguals, who in turn surpassed Returnees (EFL students: 68.8%, Returnees: 56.2%, ED bilinguals: 63.2%). Bonferroni pair-wise comparison revealed that the difference in correct percentages between EFL students and Returnees was significant ($p=.004$). There was also a main effect of place ($F(2,114)= 58.997$, $p<.0001$) and the interaction between place and group was significant ($F(4,114)=8.360$, $p<.0001$). In particular, the participants perceived the difference between /s/ and /š/ much accurately (83.5%) than that between /ɵ/ and /s/ (57.9%). The participants were below chance in perceiving the difference between /f/ and /ɵ/ (46.7%). Moreover, the participants' L2 experience was related to the perception of fricatives, as shown in Figure 4. That is, ED bilinguals performed better than Returnees, who in turn outperformed EFL students in discriminating between /s/ and /š/. However, EFL students surpassed ED bilinguals and Returnees in differentiating between other places of articulation. In fact, both ED bilinguals and Returnees were below chance in discriminating between /f/ and /ɵ/. Returnees were also below chance in distinguishing between /ɵ/ and /s/, while ED bilinguals were above chance.

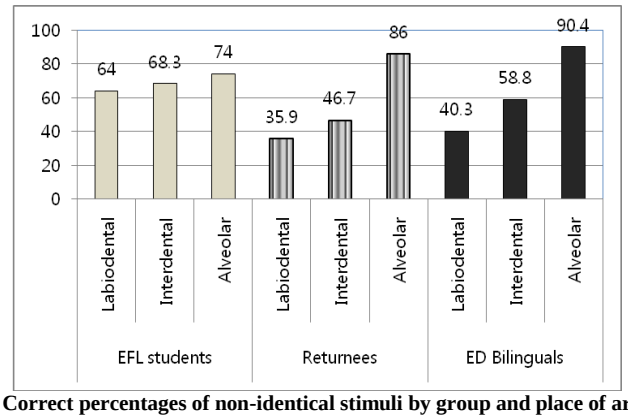

Figure 4. Correct percentages of non-identical stimuli by group and place of articulation

The fact that both ED bilinguals and Returnees had difficulty differentiating /f/ from /ɵ/ seems to suggest that they show the same error pattern as young L1 English listeners. Unexpectedly, however, Returnees and ED bilinguals were also poor at discriminating between /ɵ/ and /s/, even though it has been well-documented that Korean EFL learners have most difficulty with the distinction between /ɵ/ and /s/.

As for the results on mean RTs, there was no significant effect of group or place. The interaction between place and group was not significant, either (all p>.05).

Now, let us move onto the effect of the following vowels on the perception of fricatives. Fricatives with four places of articulation were presented before front and back vowels for both identical (e.g., *fiktom-fiktom, farbin-farbin*) and non-identical stimuli (e.g., *fiktom-thiktom, farbin-tharbin*). Paired-samples *t*-tests revealed that the following pairs showed front vs. back vowel effects on the perception of fricative sounds, as given in Tables 2 and 3.

Table 2. Identical pairs: Paired-samples *t*-tests for the difference between front and back vowels

Group	Pairs of comparison	Mean	Std. Deviation	*t*	df	*p*-value
Returnees	/s/ before FV vs. BV: AC	-.04762	.10059	-2.169	20	.042
ED Bilinguals	/ɵ/ before FV vs. BV: AC	-.11842	.19308	-2.673	18	.016

Note: AC: accuracy; RT: response time; FV: front vowel; BV: back vowel.

Table 3 Non-identical pairs: Paired-samples *t*-tests for the difference between front and back vowels

Group	Pairs of comparison	Mean	Std. Deviation	*t*	df	*p*-value
Total	/f/-/ɵ/ before FV vs. BV: AC	-.22917	.33915	-5.234	59	.000
	/f/-/ɵ/ before FV vs. BV: RT	154.83017	520.15310	2.306	59	.025
	/ɵ/-/s/ before FV vs. BV: AC	-.10000	.26119	-2.966	59	.004
	/ɵ/-/s/ before FV vs. BV: RT	103.17783	294.82191	2.711	59	.009
EFL students	/ɵ/-/s/ before FV vs. BV: AC	-.11250	.22176	-2.269	19	.035
Returnees	/f/-/ɵ/ before FV vs. BV: AC	-.42857	.30764	-6.384	20	.000
	/f/-/ɵ/ before FV vs. BV: RT	265.44381	382.91698	3.177	20	.005
ED Bilinguals	/f/-/ɵ/ before FV vs. BV: AC	-.27632	.27506	-4.379	18	.000
	/f/-/ɵ/ before FV vs. BV: RT	310.99368	222.05748	6.105	18	.000

As shown in Table 2, Returnees had higher accuracy for /s/ located before back vowels than before front vowels for identical stimuli. Likewise, ED bilinguals showed back vowel benefits for /ɵ/. As for non-identical stimuli, as shown in Table 3, the participants tended to show back vowel benefits for /f/-/ɵ/ pairs and for /ɵ/-/s/ pairs in terms of accuracy and RTs. For instance, the participants' mean rate of accuracy for /f/-/ɵ/ pairs presented before front vowels was 35%, whereas that before back vowels was 58%. Also, RTs before back vowels were 522ms, but those before front vowels were 677ms for the same pairs. Similarly, the participants' correct percentage for /ɵ/-/s/ pairs located before front vowels was 53%, while that before back vowels was 63%. RTs also showed back vowel benefits for the same pairs (back vowels: 485ms vs. front vowels: 588ms). Similar patterns were also obtained by each group.

Therefore, the results above indicate that the participants overall had more difficulty perceiving fricative sounds located before the front vowel

/i/ than before back vowels, especially when the stimuli were non-identical, which is consistent with the findings of the previous study (Gay 1970).

5. Discussion

5.1 Models of L2 speech perception

As shown in the previous section, not all nonnative sounds are equally difficult for the learners to perceive. This raises the following question on the learnability of L2/FL sounds: Why do certain sounds pose more challenges to the learners than others? In order to answer the question, let us first consider the two models of L2 speech perception, the SLM and PAM.

Both the SLM and PAM posit that the perceived phonetic similarity or difference between L1 and L2 sounds plays a crucial role in explaining learners' degree of success in perceiving nonnative sounds. More specifically, the SLM proposes that the speech learning mechanism is available across the life span and that new L2 phonetic categories can be established if acoustic/phonetic divergences between an L2 sound and the closest L1 sound are spotted. Accordingly, it is predicted that a new L2 phonetic category is more likely to be established if the perceived phonetic discrepancy between an L2 sound and the nearest matching L1 sound is great. Importantly, establishing L2 phonetic categories is essential to perceive L2 sounds native-like, as the L2 phonetic categories are the basis on which learners perceive L2 phonetic input. The SLM purports to account for how experienced L2 learners' underlying phonological representations change across their L2 learning process.

The PAM hypothesizes that certain foreign contrasts are easier or more difficulty to discriminate than other contrasts due to the perceived relationship between foreign sounds and the articulatorily closest L1 sounds. According to the PAM, when foreign sounds are quite deviant from L1 sounds in terms of perceived articulatory properties such as constriction degree, constriction place and gestural phasing, language learners can detect differences between foreign sounds and native sounds and thus they can easily discriminate the foreign sounds. The PAM considers not only phonological properties but also phonetic aspects from the L1.

According to the PAM, contrasting nonnative sounds are perceptually assimilated to L1 phonemes in one of the three ways. First, two nonnative sounds are perceived as two different L1 phonemic categories, which is termed Two Category Assimilation (TCA). When two nonnative sounds are assimilated to a single native phoneme regardless of whether both of them are good or poor exemplars of the L1 sound, it is termed Single Category Assimilation (SCA). When both nonnative sounds are categorized as a single L1 sound, but if one nonnative sound is perceived

as a better exemplar of the L1 sound than the other nonnative sound, it is termed Category Goodness Difference (CGD). The PAM predicts that discrimination of TCA is better than that of CGD, which in turn better than that of SCA. Recently, Best and Tyler (2007) expanded the PAM (called, PAM-L2) in order to predict L2 learners' perception patterns as well as those of naïve listeners with no experience with a nonnative language.

In sum, according to the SLM and PAM, if contrasting L2 sounds are categorized as the same L1 sound due to the perceived acoustic/phonetic or/and articulatory similarity between the sounds in L1 and L2, it results in discrimination difficulty. By contrast, if the L2 sound is quite different from any distinctive L1 sound, discrimination will not be difficult. This is because L2 learners can establish new phonetic categories for novel or less similar L2 sounds in the SLM. Likewise, different L2 sounds are more likely to be discriminated than similar ones in the PAM/PAM-L2.

5.2 Findings and implications for models of L2 speech perception

The results of the experiment showed that the interaction between group and stimulus type was significant, in addition to main effects of group and stimulus type. This indicates that the way stimuli were perceived was influenced by participants' different English-language experience, as EFL students were better at discriminating non-identical stimuli than Returnees or ED bilinguals were, but the latter groups were almost native-like in perceiving identical stimuli. The results also showed that overall participants with more L2 experience performed better than those with less L2 experience and that identical stimuli were perceived much better than non-identical ones (84.6% vs. 62.4%) due to lack of cognitive load, similar to the findings of previous studies (Strange and Shafer 2008).

Further, there was no main effect of place of articulation for identical stimuli, yet rather different perception patterns emerged depending on the learner group. Namely, EFL students were better on /s/ than on other places of articulation, whereas both Returnees and ED bilinguals preformed better on /s/ and /š/ than on /f/ or /ɵ/. As for non-identical stimuli, the interaction between place of articulation and group was significant, in addition to a main effect of place. Specifically, EFL students were poor at discriminating between /s/ and /š/. In contrast, both Returnees and ED bilinguals were very poor at differentiating between /f/ and /ɵ/. Further, Returnees were below chance in discriminating between /ɵ/ and /s/ and ED bilinguals were also poor at contrasting /ɵ/ with /s/. However, the overall error patterns showed that discrimination between /f/ and /ɵ/ was below chance (46.7%) and that between /ɵ/ and /s/ was also poor (57.9%) relative to the contrast between /s/ and /š/ (83.5%).

Strange and Shafer (2008) suggested that perception of place contrasts in nonnative consonants vary from poor to good. More specifically, they claimed that contrasts for place of articulation are mainly signaled by short

durational spectral differences which are not robust. Accordingly, it is predicted that discrimination of nonnative sounds' places of articulation may be difficult for the learners, even for the learners with much L2 experience.

Now, let us consider the results of the experiment in more detail in terms of each participant group. As for EFL students, they were not much different with respect to perceiving identical vs. non-identical stimuli, as their mean rate of accuracy for both types of stimuli was around 68%. EFL students' overall low accuracy seems to indicate that they had not formed separate L2 categories for the target fricative sounds due to their short experience with the English-language. Further, their performance for the identical alveolar /s/ vs. /s/ pairs and non-identical /s/ vs. /š/ pairs was much better than that for other places of articulation. This seems to indicate that EFL students might not be affected by the Korean palatalization process, as many of them were able to discriminate /s/ and /š/ even before the front vowel /i/ (73% before front vowels vs. 75% before back vowels). However, even though their discrimination of the non-identical /s/ vs. /š/ pairs was better than that of other place contrasts, their low accuracy for the identical /š/ vs. /š/ pairs compared to that of the identical /s/ vs. /s/ pairs seems to suggest that L1 interference is evident. Namely, the fact that EFL students were able to perceive only 66% of identical /š/ vs. /š/ pairs seems to indicate that many of them might not have formed a separate category for the English /š/, as [š] is a phonetic variant of /s/ in Korean, and thus EFL students might overall have more difficulty perceiving the /š/ than the /s/. Moreover, the results seem to reveal that not all predictions of the SLM and PAM/PAM-L2 hold true. According to the SLM and PAM/PAM-L2, new L2 phonetic categories can be formed if phonetic/acoustic and/or articulatory discrepancies between an L2 sound and the closest L1 sound are spotted. The English alveolar sound /s/ is very similar to the Korean sound /s/ in terms of phonetic/acoustic and articulatory properties, and thus it is expected that English /s/ would pose more problems to EFL students, which is not the case.

In addition, EFL students' perception of both identical and non-identical /f/ and /ɵ/ was around 67%. This seems to suggest that EFL students would notice that English /f/ and /ɵ/ are rather different from Korean sounds, yet they might not have established separate categories for these sounds due to the sound's similarity to Korean /p^h/ and /s'/ or /s/, respectively, in terms of air release and place properties. According to Cho and Lee (2007), English /f/ was predominantly labeled as Korean /p^h/ and English /ɵ/ as /s'/, even though rather different pictures emerged depending on the prosodic position in which the target sound occurred. Further, the SLM's postulation that the speech learning ability remains intact across the life span seems to be supported by the fact that around 67% of EFL students were able to differentiate /f/ from /ɵ/ in spite of the fact that most of them were first exposed to English at the age of 7 or later.

Now, let us turn to Returnees and ED bilinguals. Although Returnees performed better than ED bilinguals for identical stimuli regardless of fricatives' place contrasts, the latter group's discrimination for non-identical stimuli was better than that of the former group. However, overall both groups exhibited almost the same perceptual patterns. For non-identical stimuli, Returnees' discrimination of /f/ vs. /ɵ/ and that of /ɵ/ vs. /s/ were quite poor. The same holds true for ED bilinguals. This seems to suggest that Returnees and ED bilinguals show similar learning patterns concerning English /f/ and /ɵ/. Namely, /f/ and /ɵ/ exhibit similar spectral peaks known to be cues for place contrasts and the two sounds also display low intensity, which results in much difficulty for place contrasts between the two sounds (Strevens 1960, Cho and Lee 2007). Accordingly, even native English children often show difficulty with the distinction between /f/ and /ɵ/. Moreover, the sound /ɵ/ is mastered quite late relative to other sounds even by native English children, as 90% of them acquire it at around the age of 7 (Edwards 2003). Accordingly, as opposed to EFL students, both Returnees and ED bilinguals may have established separate but not perfect L2 categories (or partially merged categories) for the English /f/ and /ɵ/ sounds, as they perceived identical /f/-/f/ and /ɵ/-/ɵ/ pairs quite well, but as they exhibited great difficulty with non-identical /f/-/ɵ/ and /ɵ/-/s/ pairs. Further, according to the PAM/PAM-L2, when two nonnative sounds are classified as a single L1 sound, discrimination for the nonnative sounds is poor. Consequently, the two English sounds might be partially overlapped in categorization because of phonetic/acoustic and articulatory similarities between the two sounds, and this might result in poor discrimination. Alternatively, the results might be attributed to the fact that learners are more likely to judge similar sounds as the same sounds than to judge them as different sounds due to psychological reasons. Yet, more research should be done in order to draw a solid conclusion on the results.

Further, Returnees and ED bilinguals showed difficulty in the distinction between /ɵ/ and /s/, even though the performance of the former group was poorer than that of the latter one. As mentioned earlier, many adult Korean learners of English show much confusion between /ɵ/ and /s/. This may be due to the fact that both /ɵ/ and /s/ are coronal fricatives and thus they share many acoustic and articulatory properties, even though /s/ has a salient energy concentration between 3500 and 7000 Hz (Edwards 2003). Accordingly, Returnees and ED bilinguals might have difficulty discriminating between /ɵ/ and /s/. By contrast, both Returnees and ED bilinguals were quite good at discriminating between /s/ and /š/ and this seems to indicate that the role of palatalization in both L1 and L2 might be rather limited. That is, similar to Korean, the sound /s/ in English can be palatalized as [š] before the high front glide /j/ as in *I miss you*. Yet, /š/ also functions as a phoneme in English unlike in Korean. Thus, it appears that

both Returnees and ED bilinguals might have formed a separate category for the sound /š/ (and also for /s/), as opposed to EFL students.

Finally, let us move onto the effects of vowels. Participants showed back vowel advantages relative to front vowels for some identical and non-identical stimuli. In particular, Returnees showed a higher accuracy rate before back vowels for identical alveolar stimuli. This may be because alveolar consonants and front vowels are assumed to form a natural class as both of them involve constriction in the front part of the oral cavity (Clements and Hume 1996). In other words, the /s/ sound is made with the tongue tip raised or is at the lower front teeth and the tongue body shifted forward to be leveled toward the hard palate and channeled along its midline. For the /i/ sound, the tongue tip is at the lower front teeth and the tongue is moved forward and raised toward the hard palate. As opposed to the vowel /i/, back vowels /a/ and /ɔ/ are mainly articulated in the back of the oral cavity and the vowel /a/ does not have any contact between tongue and upper teeth and the sound /ɔ/ does not have any noticeable contact between tongue and the upper back teeth (Edwards 2003). Consequently, Returnees might have more difficulty discriminating fricatives before front vowels than before back vowels. Similar reasoning may apply to the /ɵ/ sound. That is, the constriction for the /ɵ/ sound is formed by tongue front and teeth. As a result, ED bilinguals might have shown back vowel benefits for the identical interdental stimuli.

As for non-identical stimuli, EFL students showed back vowel advantages for /ɵ/ vs. /s/ pairs. This is understandable given that the sounds /ɵ/, /s/ and /i/ are all articulated in the front part of the oral cavity, thus making place contrasts between /ɵ/ and /s/ not be salient before the vowel /i/. By contrast, Returnees and ED bilinguals exhibited back vowel advantages for /f/ vs. /ɵ/ pairs. This might be due to the fact that the sounds /f/ and /ɵ/ are quite similar in terms of their acoustic properties, as mentioned earlier, and thus the distinction between the sounds was more difficult when the following vowel was also articulated in the front cavity similar to the consonants.

In sum, the results above seem to suggest that L2 experience, along with L1 interference, figures in the perception of nonnative sounds. The results showed that L1 interference was noticeable even for learners with much L2 experience. This seems to support Strange and Shafer's (2008) claim that L1 interference may be evident even for learners with many years of L2 experience. Additionally, the results seem to support Flege's (1995) claim that both L1 and L2 phonological systems may coexist within a single phonological space. In fact, MacKay et al. (2001) claimed that a merged category which contains an L2 and its closest L1 sounds would develop over time. Further, they noted that bilinguals' perception of the L2 sounds would be different from L2 monolinguals' perception since bilinguals' perception would partially reflect typical patterns for the matching L1 sounds. Importantly, however, it was shown that participants' discrimination

of the target sounds could also be affected by phonetic/acoustic and articulatory properties of the sounds.

Appendix: Sample stimuli

1. Identical pairs:

fiktom-fiktom	thiktom-thiktom
farbin-farbin	tharbin-tharbin
siknet-siknet	thiknet-thiknet
soldum-soldum	tholdum-tholdum
sipkin-sipkin	shipkin-shipkin
soltem-soltem	sholtem-sholtem

2. Non-identical pairs:

fiktom-thiktom	thiktom-fiktom
farbin-tharbin	tharbin-farbin
siknet-thiknet	thiknet-siknet
soldum-tholdum	tholdum-soldum
sipkin-shipkin	shipkin-sipkin
soltem-sholtem	sholtem-soltem

REFERENCES

BEST, CATHERINE. 1995. A direct realist view of cross-language speech perception. In W. Strange (ed.). *Speech Perception and Linguistic Experience: Issues in Cross-Language Research*, 171-204. Timonium, MD: York Press.

BEST, CATHERINE, and WINIFRED STRANGE. 1992. Effects of phonological and phonetic factors on cross-language perception of approximants. *Journal of Phonetics* 20, 305-350.

BEST, CATHERINE, GERALD MCROBERTS, and ELIZABETH GOODELL. 2001. Discrimination of nonnative consonant contrasts varying in perceptual assimilation to the listener's native phonological system. *Journal of Acoustical Society of America* 109(2), 775-794.

BEST, CATHERINE, and MICHAEL TYLER. 2007. Nonnative and second-language speech perception: Commonalities and complementarities. In O. Bohn and M. Munro (eds.). *Language Experience in Second Language Speech Learning: In honor of J. Flege*, 13-34. Amsterdam/Philadelphia: John Benjamins.

CELCE-MURCIA, MARIANNE, DONNA BRINTON, and JANET GOODWIN. 1996/2006. *Teaching Pronunciation: A Reference for Teachers of English to Speakers of Other Languages*. Cambridge: Cambridge UP.

CLEMENTS, NICK, and ELIZABETH HUME. 1996. The internal organization of speech sounds. J. Goldsmith (eds.) *Handbook of Phonology*, 245-306. Basil Blackwell.

CHO, MI-HUI and SHINSOOK LEE. 2001. Phonological transparency and opacity in the sound substitutions of interlanguage. *Studies in Phonetics, Phonology and Morphology* 7(2), 449-468.

CHO, MI-HUI and SHINSOOK LEE. 2007. Category matching between English and Korean consonants in different prosodic environments. *English Language and Literature* 53(5), 731-753.

EDWARDS, HAROLD. 2003. *Applied Phonetics: The Sounds of American English*. Thomson.

FLEGE, JAMES EMIL. 1995. Second language speech learning: Theory, findings, and problems. In W. Strange (ed.). *Speech Perception and Linguistic Experience: Issues in Cross-Language Research*, 233-272. Timonium, MD: York Press.

FLEGE, JAMES EMIL, GRACE YENI-KOMSHIAN, and SERENA LIU. 1999. Age constraints on second-language acquisition. *Journal of Phonetics* 25, 169-186.

GAY, THOMAS. 1970. Effects of filtering and vowel environment on consonant perception. *Journal of Acoustical Society of America* 48(4), 993-998.

GOTTFRIED,TERRY. 1984. Effects of consonantal context on the perception of French vowels. *Journal of Phonetics* 12, 91-114.

GUION SUSAN, JAMES EMIL FLEGE, REIKO AKAHANE–YAMADA, and JESICA PRUITT. 2000a. An investigation of current models of second language speech perception: The case of Japanese adults' perception of English consonants. *Journal of Acoustical Society of America* 107(5), 2711-2724.

GUION SUSAN, JAMES, EMIL FLEGE, and JONATHAN LOFTIN. 2000b. The effect of L1 use on pronunciation in Quichua-Spanish bilinguals. *Journal of Phonetics* 28, 27-42.

INGRAM, JOHN, and SEE-GYOON PARK. 1998. Language, context, and speaker effects in the identification and discrimination of English /r/ and /l/ by Japanese and Korean listeners. *Journal of Acoustical Society of America* 103, 1161-1174.

IOUP, GEORGETTE. 2008. Exploring the role of age in the acquisition of a second language phonology. In J.H. Edwards and M. Zampini (eds.). *Phonology and Second Language Acquisition*, 41-62. Amsterdam/ Philadelphia: John Benjamins.

JOH, JEONGSOON, and SHINSOOK LEE. 2001. Re-examination of the role of formal instruction in L2 pronunciation. *Foreign Languages Education* 8(2), 23-44.

KIM, D.J. 1972. A contrastive study of English and Korean phonology. *Language and Teach* 5, 1-36.

KIM, SOOHEE. 1999. *Subphonemic Duration Difference in English /s/ and*

Few-to-Many Borrowing from English to Korean. Ph.D. Dissertation. University of Washington.

LAMBACHER, S., W MARTEN, B NELSON, and J BERMAN. 1997. Perception of English voiceless fricatives by native speakers of Japanese. In J. Leather and A. James (eds.). *New Sounds 97: Proceedings of the Third International Symposium on the Acquisition of Second-Language Speech*, 186-195. University of Klagenfurt Press, Klagenfurt, Austria.

LENNEBERG, ERIC. 1967. *Biological Foundations of Language*. New York: John Wiley & Sons.

LONG, MICHAEL. 1990. Maturational constraints on language development. *Studies in Second Language Acquisition* 12, 251-85.

MACK, MOLLY. 2003. The phonetic system of bilinguals. In M. Banich and M. Mack (eds.). *Mind, Brain, and Language,* 309-49. Mahwah, NJ: Lawrence Erlbaum Associates.

MACCAY, R. IAN, JAMES EMIL FLEGE, THORSTEN PISKE, and CARLO SCHIRRU. 2001. Category restructuring during second-language speech acquisition. *Journal of Acoustical Society of America* 110(1), 516-528.

OYAMA, SUSAN. 1976. A sensitive period of the acquisition of a nonnative phonological system. *Journal of Psycholinguistic Research* 5, 261-283.

PALLIER, CHRISTOPHE, LAURA BOSCH, and NÚRIA SEBASTIÁN-GALLÉS. 1997. A limit on behavioral plasticity in speech perception. *Cognition* 64, B9-B17.

SUNDARA, MEGHA, and LINDA POLKA. 2008. Discrimination of coronal stops by bilingual adults: the timing and nature of language interaction. *Cognition* 106(1), 234-258.

SCHMIDT, ANNA MARIE. 1996. Cross-language identification of consonants. Part 1. Korean perception of English. *Journal of the Acoustical Society of America* 99(5), 3201-3211.

STRANGE, WINIFRED, and VALERIE SHAFER. 2008. Speech perception in second language learners. In J.H. Edwards and M. Zampini (eds.). *Phonology and Second Language Acquisition*,153-91. Amsterdam/ Philadelphia: John Benjamins.

STREVENS, PETER. 1960. Spectra of fricative noise in human speech. *Language and Speech* 3, 32-49.

WERKER, JANET, J.H.V. GILBERT, K. HUMPHREY, and RICHARD TEES. 1981. Developmental aspects of cross-language speech perception. *Child Development* 52, 349-353.

WERKER, JANET, and RICHARD TEES. 1983. Developmental changes across childhood in the perception of nonnative speech sounds. *Canadian Journal of Psychology* 37, 278-286.

WERKER, JANET, and SUZANNE CURTIN. 2005. PRIMIR: A developmental framework of infant speech processing. *Language Learning and Development* 1, 197-234.

WHEELDON, LINDA, and WAKSLER RACHELLE. 2003. Phonological underspecification and mapping mechanisms in the speech recognition lexicon. *Brain and Language* 90, 401-412.

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