Perception of the English Epenthetic Stops by Korean Listeners*

Jeong-Im Han**

ABSTRACT

This study investigates Korean listeners' perception of the English stop epenthesis between the sonorant and fricative segments. Specifically this study investigates 1) how often English epenthetic stops are perceived by native Korean listeners, given the fact that Korean does not allow consonant clusters in codas; and 2) whether perception of the epenthetic stops, which are optional phonetic variations, not phonemes, could be improved without any explicit training. 120 English non-words with a mono-syllable structure of CVC1C2, where C1=/m, n, ŋ, l/, and C2=/s, θ, ʃ/, were given to two groups of native Korean listeners, and they were asked to detect the target stops such as [p], [t], and [k]. The number of their responses were computed to determine how often listeners succeed in recovering the string of segments produced by the native English speaker. The results of the present study show that English epenthetic stops are poorly identified by native Korean listeners with low English proficiency, even in the case where stimuli with strong acoustic cues are provided with, but perception of epenthetic stops is closely related with listeners' English proficiency, showing the possibility of the improvement of perception. It further shows that perception of epenthetic stops shows asymmetry between coronal and non-coronal consonants.

Keywords: English Epenthetic Stops, Perception, Implicit Learning

1. Introduction

Speech researchers have made efforts to identify the major possible obstacles to successful speech recognition (Jusczyk 1995). For example, although speakers of a language think they produce a sequence of discrete words, there is often considerable acoustic overlap between consecutive segments in the speech stream. However, knowledge

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** Dept. of English Language & Literature, Konkuk University

of native language sound patterns, phonotactic constraints, or other grammatical information plays a role in segmentation and fluent listeners successfully recover the appropriate units from the speech signal. Another frequently discussed possible problem to speech recognition is the so-called 'invariance problem'. There is considerable variability in the speech signal and thus it is hard to identify invariant acoustic features that could signal the presence of a particular phoneme. Thus how listeners can recognize a target sound in the spoken language is one of the most important issues in the theory of speech recognition (Cutler 1998; Weber 2001). It has been shown that listeners seem to accommodate to certain types of variability, in terms of finding certain rules among such variations.

Relevant to these issues, an interesting question to be raised here is whether such accommodation occurs even in the perception of optional phonetic variation, not a phoneme, especially when the target language including the input is not the listeners' own native language. Recently Warner and Weber (2001) reported the results of a perception study that Dutch listeners show a high rate of perception of epenthetic stops as intended by the speakers, suggesting that even optional phonetic variation could be consistently perceived by native listeners. The present study further investigates the perception of optional phonetic variation in the non-native language, focusing on Korean listeners' perception of the English stop epenthesis between a sonorant and the following fricative.

In English, epenthetic stops often appear between sonorants (a nasal or a lateral) and the following obstruents in the syllable-final position as in (1).

(1) a. sense ([sɛ**nts**]), ninth ([naɪ**ntθ**]), censure ([sɛ**ntʃ**ɚ])
false ([fɔ**lts**]), health ([hɛ**ltθ**]), Welsh ([wɛ**ltʃ**])
b. hamster ([hæ**mps**tɚ]), warmth ([war**mpθ**]), assumption ([əsʌ**mpʃ**ən])
c. youngster ([jʌ**ŋks**tɚ]), length ([lɛ**ŋkθ**]), anxious ([æ**ŋkʃ**əs])

(Clements 1987: 32)

As in (1a), [t] is inserted between a homorganic nasal or a lateral, and a voiceless fricative; [p] and [k] are inserted between a homorganic nasal and a voiceless fricative in (1b) and (1c) respectively. The application of the stop epenthesis is prohibited if the following consonant is in a stressed syllable (*consort, insert*). The epenthetic stops render the words in English such as *sense* and *false* similar in sound to the words *cents, faults*. There seems to be no motivation for stop epenthesis in terms of preferred syllable types, because such stops lead to undesirable syllable types including the complex final consonant clusters violating English phonotactic constraints.

To explain this puzzling process, there have been two types of approaches in the literature. One approach is to treat the stop epenthesis as a change in segmental phonological structure, namely, a rule of $\varnothing \rightarrow$ [p, t, k] / [son] __ [-son] (Dinnsen 1980). This approach is based on the fact that stop epenthesis applies to language or dialect specifically that should be stated in grammar. Similar formal analyses have been put forth in various formal phonological framework (Piggott and Singh 1985; Wetzels 1985, Clements 1987 among others). The other approach claims that there is a universal tendency for the articulatory system to spontaneously introduce a silent gap in such segmental sequences so as to create an acoustic effect like that of a stop (Ohala 1974; Ali et al. 1979). Following this approach, stop epenthesis is a low-level articulatory effect that does not need to be explained in grammar.

More recently, however, Fourakis and Port (1986) investigate the production of epenthetic stops in two different dialects of English: South-African and American Midwestern. They show that stop epenthesis does not result from universal articulatory constraints alone: American speakers epenthesize in every token, while South African speakers never do. However, they also show that the epenthesized stops are produced with less strong acoustic cues than the corresponding phonemes. Thus they claim that stop epenthesis is not simply a phonological rule, but dialect specific. The perception study done by Warner and Weber (2001) also shows notable results that Dutch listeners perceived - consistently - a large amount of the test tokens with epenthetic stops (approximately 50%), even though the acoustic cues of epenthetic stops were much weaker than the corresponding phonemes. However, perception of phonetic variability was shown to be affected by language-specific phonology as well as numerous phonological conditions. Based on important results of the previous work that stop epenthesis directly involves the timing relations of articulatory organs, but that its environment is defined linguistically and also language-specific, it is assumed in the present study that it is an optional phonetic process, which can be controlled by the native speakers.

At first sight, the optional phonetic variation such as stop epenthesis can cause difficulties to Korean listeners, because they are rarely aware of this covert sound structure. Without explicit training, the probability that Korean listeners pay attention to the presence of epenthetic stops between these final clusters is very low. Furthermore, Korean syllable structure constraints might hinder the Korean listeners' perception of the English epenthetic stops, because they prohibit consonant clusters from appearing in both syllable onsets and codas. Thus, for example, the underlying clusters /lk/ in *talk* 'chicken' are simplified in syllable codas (2a), while the right member of the cluster is resyllabified as an onset of the following syllable when it is followed by a vocalic element (2b).

(2) a. talk 'chicken' + to 'too' → [tak.to] 'chicken, too'
talk 'chicken' # → [tak]
b. talk 'chicken' + i 'Nominal marker' → [tal.ki] 'chicken is...'

Accepting the proposals that L1 background is generally the most influential factor in the perception of non-native contrasts (Bohn 1995), it can be predicted that Korean listeners will be less likely to perceive an epenthetic stop as real.

Given the fact that Korean does not allow consonant clusters in syllable onsets and codas, and the fact that English epenthetic stops are covert sound structures, the present study will investigate how often English epenthetic stops are perceived by native Korean listeners. Also it will be tested whether the perception of phonetic variables, not phonemes, could be improved by natural, implicit learning (without awareness of the presence of epenthetic stops). Based on the results of the study, the status of epenthetic stops as a phonological rule or phonetic implementation will be discussed.1)

2. Production

2.1 Methods

The aim of this experiment was to prepare the stimuli for the perception experiment. Though the primary purpose of the current study is to examine the perceptual aspects of Korean listeners, I also tested the production of epenthetic stops by two native English speakers.

2.1.1 Stimuli

As for stimuli for the perception experiment, phonotactically possible English nonwords containing the environment for stop epenthesis were created. As shown in Table 1, 12 nonword target items were created for each of the categories, which included monosyllabic items with coda clusters consisting of each of the nasals /m, n, ŋ/ and the lateral /l/ followed by each of the sibilants /s, θ, ʃ/

1) As one reviewer pointed out, we could see more clearly whether the perception of phonetic variables is improved, through a longitudinal study using the same subjects.

Table 1. Stimuli types. Rows indicate the nasal or the lateral of the final cluster, while columns indicate the final fricative of the cluster.

	/s/	/θ/	/ʃ/	Epenthetic stop
/m/	C[ɛ]ms	C[ɛ]mθ	C[ɛ]mʃ	[p]
/n/	C[ɛ]ns	C[ɛ]nθ	C[ɛ]nʃ	[t]
/ŋ/	C[ɛ]ŋs	C[ɛ]ŋθ	C[ɛ]ŋʃ	[k]
/l/	C[ɛ]ls	C[ɛ]lθ	C[ɛ]lʃ	[t]

C = /m, n, r, l, s, tʃ, f, w, j, h/

The items began with one consonant (never a stop) and had a mid lax vowel [ɛ], followed by the nasal or lateral plus fricative cluster. All target items were listed in Appendix A. An additional 63 phonotactically legal nonwords or real words, consisting of monosyllabic items, were created as fillers. In these words, the expected epenthetic stops were included as phonemes as in /pin/. In each category, 10 consonant types for an initial consonant were chosen and thus test words were all told 183 (12 categories×10 C types+63 fillers).

2.1.2 Subjects and procedure

Two male native speakers of English (General American Dialect) who had backgrounds in linguistics, but did not know the purpose of the experiment were recorded. None of the participants had a history of hearing and speaking disorders. All materials were recorded onto a CSL(model 4400 B) and sampled at 22,050 Hz. Stimulus items and fillers were presented in random order in mixed forms of the Roman alphabet and IPA. The speakers were given the chance to familiarize themselves with the materials, and then began the experiment. The speakers were instructed not to produce final fricatives as voiced. Epenthetic stops were not marked in the materials presented to the speakers and thus the presence of epenthetic stops was not exposed to the speakers. The waveforms and spectrograms for each cluster were displayed to measure the closure duration of the epenthetic stop and to count the number of tokens with epenthetic burst. The duration of stop closure was measured, from cessation of nasal voicing to the beginning of the frication noise.

2.2 Results and discussion

Before reporting the production results of the speaker, we should be more clear as to the acoustic cues for epenthetic stops. Even though it is not easy to determine from acoustic information alone whether a given token was produced with an epenthetic stop, there have been two proposals for the primary acoustic correlates of the epenthetic stops. Fourakis and Port (1986) claim that any gap between the sonorant and the final fricative with no acoustic energy visible on the spectrogram should be considered to be a voiceless stop if its duration exceeds 10 ms. On the other hand, Warner and Weber (2001) argue that an epenthetic stop burst is sufficient to show that an epenthetic stop is produced. A token was considered as having an epenthetic burst if there was a broadband burst-like noise visible in the spectrogram either late in the intended stop or just before the frication noise. In the present study, I followed both of these criteria: I measured the closure duration between the nasal/lateral and the following fricative; and also evaluated the proportion of test tokens produced with epenthetic bursts before the fricatives. Figure 1 shows sample waveforms and spectrograms for test tokens with epenthetic stops.

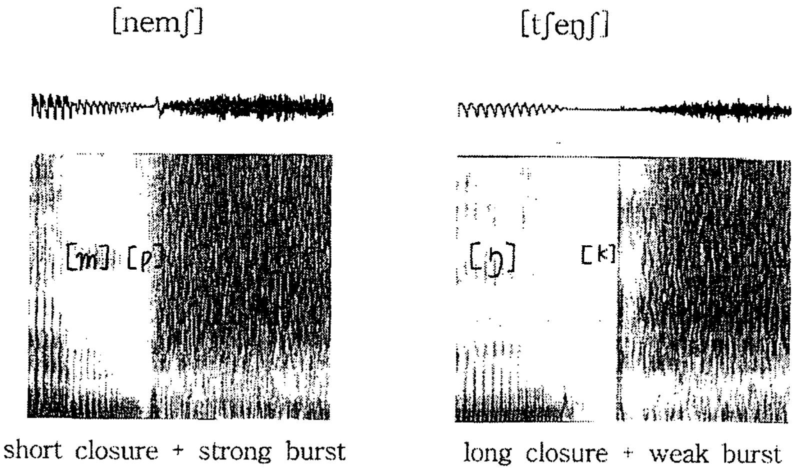

Figure 1. Left: Waveforms and spectrograms of the test tokens with a short closure duration and a strong burst; Right: those with a long closure duration and a weak burst.

The average closure duration between a sonorant and a fricative and also the proportion of items with epenthetic bursts are shown in Table 2.

Table 2. Closure durations and the number of tokens with epenthetic bursts of the final clusters.

final cluster	closure duration (ms)		number of tokens with epenthetic bursts	
	NE1	NE2	NE1	NE2
ms	36.7	5.04	10 (10)	5 (10)
mʃ	12.6	2.16	10 (10)	3 (10)
mθ	11.1	27.31	3 (10)	7 (10)
mean (labial)	15.82		7	
ns	19.9	0.0	9 (10)	2 (10)
nʃ	1.1	1.74	5 (10)	6 (10)
nθ	18.3	14.02	3 (10)	3 (10)
ls	0.0	2.65	0 (10)	0 (10)
lʃ	0.0	0.0	0 (10)	0 (10)
lθ	0.0	0.87	0 (10)	0 (10)
mean (coronal)	5.39		2.34	
ŋs	58.3	4.76	9 (10)	2 (10)
ŋʃ	34.4	33.59	9 (10)	7 (10)
ŋθ	48.2	20.36	9 (10)	4 (10)
mean (dorsal)	33.29		6.65	

(NE=native English speaker)

As in Table 2, both the closure duration and the realization of epenthetic bursts varied according to the speaker, and also the type of consonant clusters the epenthetic stops were expected to occur. Counter to the phonological account where stop epenthesis appears between a sonorant such as a nasal or a lateral and the following obstruent, the lateral did not trigger the stop epenthesis. NE2 produced only a small number of items with epenthetic [t] between a lateral and a sibilant cluster; no single item was produced for NE1. This result might have to do with the way the American English speakers articulate /l/ in the coda position. The /l/ in American English possesses two clearly distinguishable allophones, commonly referred to as light l and dark l. When /l/ precedes a vowel (leave), the tongue tip is touching the alveolar ridge (light l). On the other hand, the dark l is made when the /l/ is in the medial position before an unstressed vowel (telephone), or in the final position (fill). The /l/s in the stimuli of the present study are all posited in syllable coda position and thus possess the quality of dark l. A major portion of the tongue is elevated toward the velar part of the mouth, but rarely touches the velum so that the tip of the tongue no longer makes contact with the alveolar ridge. Therefore, this sound is more like a kind of back vowel (Ladefoged 2001). The vowel-like quality of /l/ may hinder the formation of pressure build-up enough to form an epenthetic stop. Even though this account needs further systematic research, the impressionistic rule description that the stops are epenthesized between the lateral and the fricative clusters should be revisited based on the results of the phonetic experiment.

The places of articulation of the preceding nasals also influence the proportion of the stops inserted. The dorsal nasal plus a sibilant clusters are most likely to be produced with epenthetic stops, and the clusters with a coronal nasal and a sibilant are least likely to be produced with epenthetic stops. The clusters with a labial and a sibilant cluster are intermediate. The detailed explanation for this discrepancy will be presented later.

Of the two speakers, the recording of the speaker (NE 1) who showed much larger numbers of epenthetic stops in production was chosen for use as stimuli for the perception experiment. As mentioned earlier, whether a given token was produced with an epenthetic stop was determined in two ways. Following Fourakis and Port (1986), the duration of the silence gap between a nasal or a lateral and the following fricative was measured. On the other hand, Warner and Weber (2001) evaluated the number of tokens produced with epenthetic bursts. The production results of NE 1 show that native English speakers tend to produce the target tokens with both a silent gap and an epenthetic burst. Only small numbers of tokens were shown to be produced either with a silent gap alone or only with an epenthetic burst. Only 17 items out of 120 were produced exclusively with a silent gap or with an epenthetic burst, even though the exact number of tokens showing such inconsistency varies slightly according to the positions of the intended epenthetic stops.

To run a perception experiment, however, we assume that each token was produced with epenthetic stops if it was produced with either more than 10 ms of closure or with a strong burst. Following these criteria, the average proportions of the test tokens which were considered to be produced with epenthetic stops in each cluster were as presented in Figure 2.

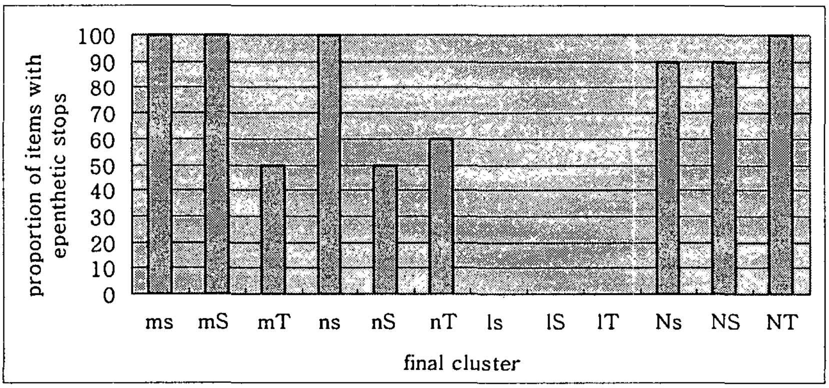

Figure 2. Percentage-proportions of test tokens produced with epenthetic stops in each cluster. (S=[ʃ], T=[θ], N=[ŋ])

3. Perception

3.1 Methods

3.1.1 Subjects

Two groups of listeners took part in the experiment. The first group were native listeners of Korean with a low proficiency in speaking and listening English, who were college students or graduate students. The second group were native Korean listeners with a high proficiency in English, almost bilinguals of Korean and English. These two groups are called 'native Korean (NK)', and 'bilingual' respectively. Each group consisted of 20 listeners and they were all paid for their participation.

3.1.2 Procedure

As for the experimental task, the General Phoneme Monitoring Procedure (Connine & Titone 1997; Frauenfelder & Segui 1989; Warner & Weber 2001) in which subjects had to listen to speech and detect the predetermined target sound within the test words was used. Each subject was instructed to mark the space for each token when subjects thought they heard the target stop sounds such as [p], [t], and [k] anywhere in the test words, given the notice that not all tokens contained the target sounds. The subjects were tested one at a time in a quiet room and the stimuli were presented to the subjects through headphones three times. After some trial set of stimuli were given for the subjects to familiarize themselves, each subject heard all the test tokens and filler items in randomized order. The perception experiment lasted around 40 minutes for each subject. After the experiment, it was checked whether the subjects knew the presence of epenthetic stops. The number of correct responses to the target sound in the phoneme monitoring was measured. These numbers of responses can determine how often listeners perceive the epenthetic stops produced by the speaker.

3.2 Results and discussion

Table 3 shows the average proportion of stimuli in which each group of NK subjects responded to epenthetic stops produced by the NE speaker.

Table 3. Mean percentage of correct responses to epenthetic stops

group	Native Korean	Bilingual
mean	26.79	47.97
range	22.78 - 30.80	43.96 - 51.98
number of tokens	180	180

As in Table 3, native Korean listeners perceived only small numbers of English epenthetic stops (26.79% of the test words which were produced with epenthetic stops). These listeners also show a wide range of responses as compared to the other groups of listeners. As compared to these native Korean listeners, bilingual listeners show higher rates of perception of the epenthetic stops (47.97%) than the NK listeners. The difference between these two groups was significant ($t(358)=-5.611$, $p<.05$ by independent samples t-Test). At first glance, it seems that even the bilingual listeners show response rates below the chance level. However, it can be said to be a rather high rate of perception based on two facts. First, the native English speakers did not produce the epenthetic stops intentionally, because these stops are not phonemes in English. Rather the epenthetic stops were produced as a matter of variation in the timing of gestures. Thus epenthesized stops were produced with much weaker acoustic cues such as a shorter duration and a weaker amplitude of epenthetic burst than the corresponding stop phonemes, which were produced intentionally. The other fact is based on the results of the previous perception study by Warner and Weber (2001), where even the listeners whose phonotactic constraints do allow consonant clusters perceived epenthetic stops approximately 50% of the time in the test words which present the environment for epenthesis. Thus it is likely that native Korean listeners with a high level of English proficiency had little problem processing the epenthetic stops in English. The overall high rate of these subjects reporting epenthetic stops in this study suggests that even without any explicit training, perception of phonetic variables, not phonemes, could be improved by learning.

However, perception of the epenthetic stops varied according to the place of articulation of the preceding nasals as shown in Figure 3. Figure 3 shows the average proportion of stimuli in which subjects responded to epenthetic stops in each place of preceding nasals. The results for the final clusters including a lateral were not included, because no single item was produced with epenthetic stops in the production experiment.

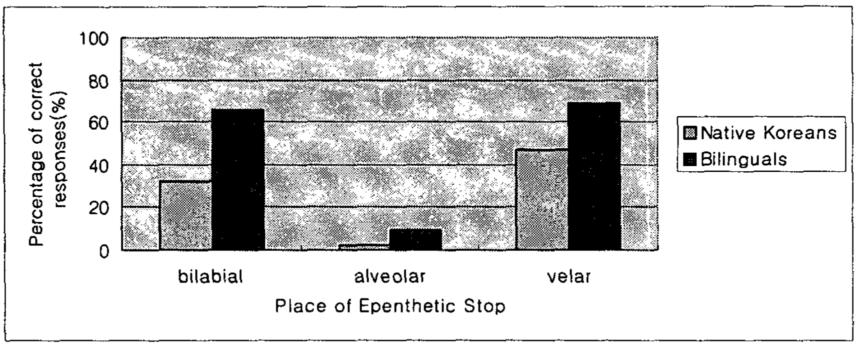

Figure 3. Average proportion of correct responses to epenthetic stops for each of articulation

In Figure 3, it was shown that there are significant differences across final cluster types in how often epenthetic stops were perceived. Also, there are significant effects of interaction of final cluster types and the proficiency levels. The ANOVA yielded significant differences across the cluster types [$F(2,354)=123.165$, $p=0.000$], and also significant cluster type x proficiency level interaction, $F(2,354)=6.8880$, $p=0.001$. The results in Figure 4 indicate that in the clusters including the velar nasal plus a fricative, listeners responded to epenthetic stops very often, while the alveolar nasal plus fricative clusters receive very few responses. The clusters with a labial nasal and a fricative are intermediate.

Figure 4 more clearly shows the difference in the perception of epenthetic stops among various cluster types and also between two proficiency groups, even though any single cluster type was found to have a larger number correct responses among the bilingual listerners.

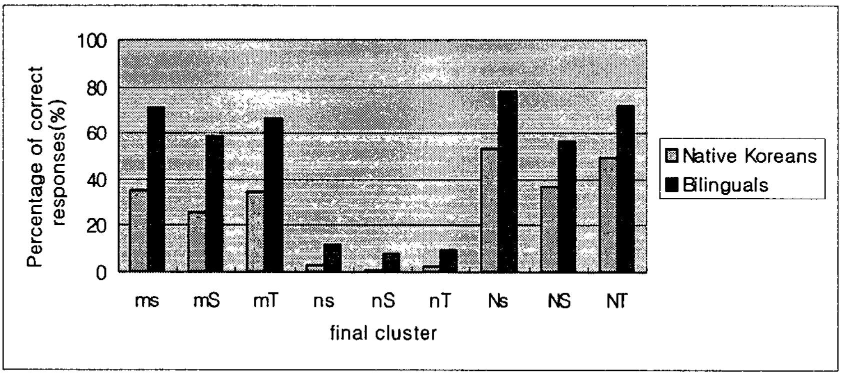

Figure 4. Average proportion of correct responses to epenthetic stops for each cluster type (S=[ʃ], T=[θ], N=[ŋ])

4. General Discussion

4.1 Perception of optional phonetic variation in a non-native language

The results of the perception experiment show that native Korean listeners (with a low level of proficiency in English) rarely perceive the English epenthetic stops, but Korean-English bilinguals (with a high level of English proficiency) perceive epenthetic stops approximately 50% of the time in nonwords which present the environment for epenthesis.

Focusing on the results of the subjects with low proficiency in English, it was shown that epenthetic stops which are produced as a matter of variation in the timing of gestures are not easily perceptible. Considering the results of an earlier study by Weber and

Warner (2001) where even the optional phonetic variation such as epenthetic stops is consistently and well processed by Dutch listeners, the results of the present study suggest that perception of the optional phonetic variation is not easy when it is provided in non-native languages. These difficulties in the processing of the optional phonetic variation in L2 suggest that the covert sound structures in a non-native language are not easily perceived and/or processed. The phoneme sounds are generally learned by explicit instruction, but the optional phonetic sounds are rarely discussed in the class and thus not likely to be attended to by L2 learners. Also, these processing difficulties might suggest that L1 phonotactic constraints influence the perception of the optional phonetic contrasts in L2. Korean does not have consonant clusters in syllable onsets and syllable codas. As a result, test tokens with a structure of CVCCC cannot be easily processed by Korean listeners.

The results of the perception experiment indicate that the stop epenthesis is not just a low-level, phonetic-implementation process as discussed in several phonetic studies (Ohala 1974 among others), but language-specific. Ohala (1974) suggests that there is a universal tendency for the articulatory system to spontaneously introduce a silent gap in the sonorant and fricative sequences, which corresponds to a stop. Stop epenthesis thus has a low-level articulatory effect which is external to the linguistic grammar. However, very few responses to the epenthetic stops by native Korean listeners as presented in this study do not support this approach. Rather the results of the present perception experiment are consistent with those of the production study by Fourakis and Port (1986), where language-specific characteristics of stop epenthesis are shown between American and South African speakers. But this does not mean that stop epenthesis is a phonological rule as proposed by several phonological analyses such as Clements (1987) and Dinnsen (1980). Stop epenthesis was shown to be a kind of phonetic, not phonemic, process (Warner and Weber 2001). Based on the observation that English stop epenthesis is not phonetic implementation, but language-specific; and that it results from the variation in the timing of gestures, the stop epenthesis should be treated in language-specific phonetic grammar (Keating 1986; Kingston and Diehl 1994).

On the other hand, the results for the highly proficient listeners in English show that they perceive epenthetic stops a great deal of the time. Again, 50% is a rather high rate of perception, considering the facts that the English native speaker did not produce the epenthetic stops intentionally; and even Dutch listeners show similar rates of perception of epenthetic stops whose phonotactic constraints do allow consonant clusters in the coda position. Thus it could be assumed that the native Korean listeners with high English proficiency process the English epenthetic stops up to the level of native speakers. This shows that epenthetic stops, which are produced as a matter of variation in the timing of gestures, are perceptible as much as in the case of stop phonemes despite their weak acoustic cues if the listeners' general proficiency in L2 is high enough.

The results of the present study suggest the possibility of implicit learning without awareness in that the bilingual listeners received no formal instruction on the English epenthetic stops (Carr & Curran 1994; Curran & Keele 1993; Tomlin & Villa 1994; Velmans 1991 among others). Additionally, they have had little chance to be aware of the epenthetic stops. In fact, even native speakers of English do not consciously recognize the presence of epenthetic stops. Without being aware of the presence of epenthetic stops in English, the Korean-English bilingual listeners showed statistically significant improvement in their ability to perceive the epenthetic stops. At the earlier stage of learning, it seems that the Korean phonotactic constraints not allowing consonant clusters in syllable codas inhibit Korean learners' perception of English epenthetic stops. This can be clear from the fact that the native Korean learners with a low level of proficiency in English showed difficulty in processing English epenthetic stops. However, the inhibition by L1 phonotactic constraints is likely to be overcome as Korean learners' general proficiency in English increases and English epenthetic stops can be perceived. The improvement of their perception of English epenthetic stops can be regarded as the learning of an optional phonetic variation in a non-native language and the learning is accomplished under the natural environment, without any explicit training on, and thus any awareness of, the presence of epenthetic stops.[2)]

4.2 Coronal vs. non-coronal asymmetry

We have observed the asymmetry between coronals and non-coronals in the perception of epenthetic stops: Korean listeners, whether they are highly proficient or rarely proficient in English, are less likely to respond to epenthetic [t] than to epenthetic [p] or [k]. It has been widely acknowledged that [t] has a special phonological status: it is the least marked segment and thus often assimilates to the place of the following consonant or even deleted (Paradis and Prunet 1991). Earlier phonetic studies explain these coronal vs. non-coronal asymmetries in terms of the acoustic differences in the production of the stops for each place. Warner and Weber (2001) claim that the high rate of responses to epenthetic [k] may reflect not only the prevalence of epenthetic bursts and/or long closure durations in these stimuli, but also the fact that [k] has the longest resonating cavity anterior to the constriction, leading to louder bursts for [k] as compared to [p] and [t] Also Stevens (1998) shows that the velar stop tends to have longer bursts than any other stops. These

2) Many of the ideas about implicit learning have emerged from an ongoing discussion between Jong-Bai Hwang and myself. See Han and Hwang (2003) for a more detailed explanation.

strong acoustic cues such as louder and longer bursts can lead to a high rate of perception of the epenthetic [k].

Unmarked phonological nature and weak acoustic cues found in the coronal stops as compared to the corresponding non-coronal stops have to do with less perceptual salience of [t] than any other places of articulation (Jun 1996). Hume et al. (1999) and Jun (1995, 1996) suggest that greater perceptual salience of a given segment is a result of more robust cues and a better cue package. By proposing the universal salience ranking for unreleased stop consonants (which are the same environments for the epenthetic stops) as in the order of dorsal, labial, and coronal, Jun (1995, 1996), for example, claims that the acoustic cues for coronal in this position are weak as compared to those for the dorsal and labial. This claim is attributed primarily to the observation that the tongue gesture of the coronal stop is rapid, resulting in short transitional cues. On the other hand, more sluggish gestures for labials and dorsals lead to longer transitions, which can give more information to the listeners.

The results of the production experiment as presented in Table 2 clearly show that coronal epenthetic stops [t] have much weaker acoustic cues than those for labials [p] and dorsals [k] in terms of closure duration and stop bursts. The mean closure duration was 15.82 for the epenthetic [p] and 33.29 for the epenthetic [k], but 5.39 for the epenthetic [t]. The mean number of epenthetic bursts also varied according to the place of articulation: 7 out of 10 for the epenthetic [p] and 6.65 for the epenthetic [k], but 2.34 for the epenthetic [t]. Thus the mean closure duration of the non-coronal stops was longer than that of the coronal stops; the epenthetic bursts of the non-coronal stops occur more frequently than those of the coronal ones. Overall, the acoustic cues the coronal stops show were much weaker than those for the non-coronals. Assuming that these two acoustic cues are possible potential cues for the epenthetic stops, these weaker acoustic cues might lead to relatively lower rates of perception of epenthetic [t] as compared to [p] and [k].

However, the lack of sufficient cues in production alone does not seem to account for the low number of responses of [t], because there was the case where the final cluster with a weaker acoustic cue was more likely to be perceived. If we examine the results in Table 2 again, the mean closure duration of /mθ/ cluster is shorter than that of /ns/ or /nθ/ cluster; the number of tokens with epenthetic bursts in the /mθ/ cluster are lower than those in /ns/ or /nʃ/ cluster. But Figure 3 shows that the listeners were more likely to respond to epenthetic [p] in /mθ/ cluster than to epenthetic [t] in /ns/, /nʃ/, or /nθ/ cluster. Thus listeners did not perceive the signal as containing that stop even in the presence of enough acoustic cues, implying that there seems to be perceptual effects per se as well as differences in production, even though the nature of those effects are far from clear at present.

5. Conclusion

The present study investigated Korean learners' perception of the epenthetic stops in the American English. The results of the experiment show that the native Korean listeners responded to only a few items with epenthetic stops, but Korean-English bilinguals perceived the epenthetic stops almost like native listeners. These results show that 1) the stop epenthesis is not low-level phonetic implementation, but language-specific as claimed by Fourakis and Port (1984); and 2) perception of the optional phonetic variation such as epenthetic stops can be improved as overall language proficiency grows, showing the possibility of implicit learning without awareness.

However, perception of the epenthetic stops shows asymmetry between coronal and non-coronal consonants. Whether their English proficiency is high or low, Korean listeners are less likely to respond to epenthetic coronals than to epenthetic labials or velars. These results appear to be related to the differences in their acoustic cues as well as perceptual effects.

In summary, perception of the English epenthetic stops by Korean listeners show both language-universal and language-specific characteristics, based on the coronal vs. non-coronal asymmetry and the poor identification of the optional phonetic variation in L2, respectively. Although listeners' perceptual abilities are influenced by their native language experience, they are also shaped by language-universal sound patterns.

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▲ Jeong-Im Han
Dept. of English Language & Literature
Konkun University
Tel: +82-2-450-3339
E-mail: jhan@konkun.ac.kr