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L1 Interference in Koreans' Perception of Released Word-final Stops in English

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This study investigated L1 interference in the perception of released word-final stops in English by performing perception experiments on Korean and English listeners. Stimuli with conflicting cues were used in experiments in which the 'long CV' and the 'short vowel CV' were rejoined with six silent closure duration intervals and two release bursts of [g] and two release bursts of [k]. The perception results show that Korean listeners perceived significantly more [k] compared to English listeners when 'k' release was attached to a 'long CV.' We suggest that this is due to different phonological systems in Korean and English. In Korean, a released stop occurs only in the onset position in which the VOT and the stop closure duration are important acoustic cues for the identity of a stop. Thus, the English coda [k] with voiceless release burst could be perceived as an onset with long VOT, namely [k], by Korean listeners. In contrast, English listeners mostly perceived a voiced stop due to the long preceding vowel (cf. Raphael, 1972). With the stimuli of 'short CV' with 'g' release, Korean listeners perceived significantly more [g] than NE listeners did. English coda [g] with a voiced release may be perceived as an onset [g] with a short VOT by Korean listeners. In contrast, English listeners perceived a voiceless stop [k] due to the preceding short vowel. This paper also showed that Korean listeners would perceive finer distinctions than two levels of release, 'g' release and 'k' release.

Key Words: L1 interference, perception, released word-final stops in English, conflicting cues, release bursts

1. Introduction

Voicing contrast of stops in world languages are represented with various acoustic cues like VOT (Liberman, et al., 1958; Lisker & Abramson, 1970), the closure duration of stops (Lisker, 1981; Raphael, 1981), the presence or absence of voicing during closure (Raphael, 1981; Hillenbrand et al., 1984), vowel duration (Raphael, 1972; Hogan & Rozsypal, 1980), C/V ratio (Port & Dlaby, 1984), and so on.

These acoustic cues are encoded differently in stops depending on the languages and the phonological contexts in which they occur. In English, VOT is shown to be the most salient acoustic cue for the voicing contrast of stops in the word-initial position: Voiceless stops show long VOT while voiced stops show short VOT. In word-final position, the duration of the vowel before the stop is the most salient acoustic cue for the voicing contrast: The vowel is longer if the following stop is voiced compared to the voiceless one. In case the word-final stop is released, the stop closure duration also plays a role in the voicing contrast: Closure duration is longer for the voiceless stop than for the voiced stop. Other acoustic cues such as the voicing during closure duration and the burst release of a stop also contribute to the perception of voicing contrast.

Korean does not show the voicing contrast of stops. Instead, Korean has three different stop categories with different manners of articulation, namely, lax, aspirated, and tense (Lisker & Abramson, 1964; Kim, 1970; Han & Weitzman 1970). English stops with the voicing contrast are often perceived as one of these Korean stop categories, i.e., English voiceless stops as Korean aspirated stops, and English voiced stops as Korean lax stops.

It has been shown that the difference in cross-language speech perception can be explained with different phonological systems and phonetic cues in languages (Best et al., 1988). Different phonological systems in L1 and L2 languages interfere with listeners' perception of distinctive sounds. For instance, English has /r/ and /l/ contrast while Japanese does not. Many studies have shown that Japanese learners of English experience great difficulties in differentiating /r/ from /l/ (Goto, 1971) as L1 Japanese interferes with their perception of the sounds.

Another instance comes from Korean. Korean has voiceless alveolar fricative

contrast, lax [s] ([ㅅ]) and tense [S*] ([ㅆ]), while there is only one voiceless alveolar fricative [s] in English. Kang and Yoon (2005) showed that Korean listeners perceived two distinctive Korean phonemes, lax [s] and tense [S*], from one English phoneme [s]. If the temporal duration of English fricative [s] is relatively long, Korean listeners perceive it as tense [S*] whereas with the relatively short duration of English fricative [s] Korean listeners perceive it as lax [s].

Different acoustic cues were also shown to induce the variability in cross-language speech perception. Crowther and Mann (1992) examined whether vowel duration and F1 offset transition influenced the perception of a stop for different language speakers such as English, Japanese, and Mandarin speakers, and showed that the different perception of the voicing contrast of English stops occurred depending on the L1 of the subjects. English speakers used vowel duration most effectively in the voicing contrast of stops compared to other language speakers.

The present study attempts to investigate the variability of cross-language perception between native Korean listeners (NK listeners) and native English listeners (NE listeners) for the released word-final stops in English. As the acoustic cues and the phonological status of stops in these two languages induce variability in the perception, let us examine these matters in detail.

It is well documented that the main phonetic cue of word-final English stops is the preceding vowel length in English (Raphael, 1972; Hogan & Rozsypal, 1980). On the other hand, the release burst of the stop is a redundant feature in this position, if it occurs. It helps to clarify the voicing contrast of the stop. In Korean, three types of stops such as aspirated, lax, and tense stops are all voiceless and acoustic cues utilized to distinguish these three stops are VOT, the F0 of the following vowel, and the closure duration.

Specifically, first, VOT is progressively longer for tense stops, lax stops, and aspirated stops (cf. Lisker & Abramson, 1964; Kim, 1970; Han & Weitzman, 1970), though VOT ranges of the stops with different manners of articulation often overlap (Lisker & Abramson, 1964; Kim, 1970; Silva, 1992, 2006). In addition, if lax stops occur between vowels, they very often become voiced.

Second, the F0 levels of the following vowels distinguish different types of stops. Vowels that follow aspirated and tense stops show higher F0 levels than those following lax stops (Han & Weitzman, 1970; Jun, 1993).

Third, different types of stops show different closure duration. Lax stops show the shortest closure duration while tense stops show the longest closure duration. Aspirated stops show closure duration that is between that of tense and lax stops (Silva, 1992; Han, 1996).

In addition to phonetic differences, phonological differences also exist between English stops and Korean stops. In the word- or syllable-final position, Korean phonology does not allow a released stop: All three types of Korean stops are neutralized in the coda position as the unreleased lax stop. Thus, when Korean listeners hear a released English word-final stop, L1 Korean may interfere with Korean listeners' perception and affect them to perceive it as an onset since a released stop occurs only as an onset in Korean phonology.

The category of a stop in an onset position is determined by VOT and the closure duration in Korean. Thus, the release burst of the English word-final stop will be perceived and evaluated in terms of these distinctive cues such as VOT, its amplitude, and the closure duration, by Korean listeners. If the release burst is voiceless and long, and its amplitude is high, it is more likely to be perceived as an aspirated stop. If the release burst is voiced and short, and its amplitude is low, it is more likely to be perceived as a lax stop. Note that a lax stop often appears as a voiced stop in the intervocalic position. In short, the acoustic cues of the release burst could be perceived as the acoustic cues of an onset, the perceptually salient position, by Korean listeners while they are perceived as acoustic cues of a redundant feature of the coda stop by English listeners. It is reasonable then that Korean listeners may show more sensitivity to the acoustic cues of the release burst of the English final stop than English listeners do.

The closure duration of the stop is also available by the release point of word-final stop. English uses two levels of closure duration for voicing contrast, long and short, while Koreans may use three levels of closure duration to distinguish three types of stops: long for tense stops, intermediate for aspirated stops, and short for lax stops (cf. Silva, 1992; Han, 1996). English listeners and Korean listeners are likely to use different closure durations for their respective stops, voiced vs. voiceless in English and lax vs. tense vs. aspirated in Korean.

In short, Korean and English use many acoustic cues such as release cues, closure duration cues, and vowel length cues to differentiate stop categories. According to Burnham (1986), phonetic cues of speech contrast can be divided

into two types, "robust" and "fragile." Burnham (1986) suggests that distinctive temporal acoustic dimensions are "robust" phonetic cues while spectral acoustic differences are "fragile" acoustic cues. The acoustic cues that we are going to examine in this paper could be considered "robust" cues since they are temporal cues, such as duration of release burst, consonant closure duration, and vowel length. Thus, it is expected that performance by Korean and English listeners in the perception of English-final released stops might rather clearly demonstrate the relative effectiveness of these cues depending on their native languages.

Park and Kang (2006) performed the experiment in which conflicting cues of English word final stops were provided to listeners. They showed that English listeners revealed more sensitivity to the preceding vowel than the other intervals in determining the voicing contrast as expected. However, they argued that Korean listeners showed more sensitivity to the preceding vowel interval if background signals were voiceless, but if the background signals were voiced, Korean listeners showed more sensitivity to the stop closure duration. They did not offer any explanation why different perception results were obtained between native English listeners and native Korean listeners. This paper will examine whether their results are maintained. This paper will also offer phonological explanation for the perceptual results.

In order to examine the relative effectiveness of these acoustic cues in Korean and English, this paper will use a phoneme-decision task using the stimuli of English word-final stops with subcategorical mismatches (Whalen, 1984). In particular, this paper will use the word-final velar stops as stimuli. Velar stops were chosen since they were released more often than other stops word-finally and their releases are more audible. Velar stops were released 83.11% of the time in the TIMIT data base[1)] compared to 49.5% of the time for bilabial stops and 57% of the time for alveolar stops according to Byrd (1993). In addition, velar stops contain more audible release possibly due to aerodynamic reasons (Byrd, 1993).

This paper consists of as follows: In Chapter 2, we will examine whether Korean listeners and English listeners perceive differently when various release bursts are presented in various contexts. Chapter 3 summarizes the implications of the perceptual results.

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1) The TIMIT database was designed for automatic speech recognition according to Byrd (1993).

2. Experiments

2.1. Procedures

2.1.1. Talkers

Two native English talkers participated in the recording. The American talker (male, Talker OR hereafter) was born, raised, and lived in US until he came to Korea to teach. The other talker is British (female, Talker JU hereafter), born in Britain, and spent her life in Britain until she came to Korea to teach.

2.1.2. Stimuli for Production

The target sounds are English word-final stop [k] and [g] sounds. We chose two words, "knack" and "nag," as stimuli for the recording. The talkers were asked to produce the tokens, "knack" and "nag," naturally but with the final release. The tokens were produced without the carrier sentence. The talkers produced eight tokens of "knack" and eight tokens of "nag."

2.1.3. Stimuli for Perception

We used splicing techniques to make the stimuli in the perception experiments. From the speech tokens of "nag" and "knack" produced by Talkers OR and JU, we first segmented the initial CVs, the closure durations, and the final release bursts. From these, we then selected one CV, "nag" token from each talker. The CV "nag" from two talkers will be referred to as 'long CV' (or 'long nag').

From these two long versions of "nag," we created short versions of "nag," which will be referred to as 'short CV' (or 'short nag'). The 'short nag' was constructed by taking out the central portion of the vowel from each 'long nag' by approximating the vowel duration of "knack" of each talker. The closure duration of the final released stop was replaced with six different silent closure durations in 30 msec steps over the ranges of 40 msec to 190 msec. The shortest closure duration reflects the closure duration of the voiced stop and the longest one reflects that of the voiceless stop. As for the release burst tokens, four different release burst tokens were selected from each talker, two from the voiced stop category [g] and the other two from the voiceless stop category [k].

Two tokens from each stop category were chosen depending on the duration and amplitude: one token with the longest duration and high amplitude, and the other token with the shortest duration and low amplitude.

In Table 1, we provided the vowel durations of 'long nag' and 'short nag,' and release bursts of two types from the voiced stop [g] and the voiceless stop [k] used in the experiments.

Table 1. The durations of the final released stops

	Talker JU	gloss
VD of a 'long CV'	355 ms	245 ms
VD of a 'short CV'	187ms	133 ms
'g1'	137 ms	53 ms
'g2'	130 ms	47 ms
'k1'	131 ms	92 ms
'k2'	165 ms	99 ms

*VD=vowel duration

Four versions of release bursts were combined with six consonant closure duration intervals to yield 24 stimuli for each vowel duration. In total, 48 tokens were created for each talker: 2 CV types (1 long CV and 1 short CV) * 6 closure steps * 4 release types= 48 tokens.

2.1.4. Listeners

Sixteen NK listeners and six NE listeners participated in the perception study. The sixteen native Korean students are university students in Korea. The NE listeners (two females and four males) are English instructors (3 Americans and 3 Canadians). No one has any speaking or hearing problem and all participants were paid a small amount of money for participation.

2.1.5. Word Identification Task

Sixteen NK listeners and six NE listeners participated in a forced-choice word identification task. They were instructed to listen to a target word and select the word that matches the stimulus best. Two options were shown on the computer screen, 'knack' and 'nag.' The auditory stimuli were played at a

comfortable loudness level, and the same loudness level was maintained for all subjects.

The test consisted of five blocks. The first block contained 12 stimuli for practice. Twelve stimuli contained the 'long nag' and 'short nag' produced by Talkers OR and JU, to get participants to be familiarized with the vowel length of stimuli. The remaining four blocks were actual perception tests. Each block contained 48 stimuli of one talker. Two blocks were the stimuli from Talker OR and the other two blocks were the stimuli from Talker JU. Each auditory stimulus was played once (and one 'replay' option was provided but it was not recommended to use it). The listening experiment lasted approximately 30 minutes.

2.2. Experiment 1

2.2.1. Results

This section examined whether different perception responses were induced when subjects were presented with 'long CV' stimuli attached with different release types, 'g' and 'k,' and different closure duration intervals. The correct responses as [g] at each duration interval (6 intervals) were submitted to a two-way repeated measures ANOVA with release types (2 release types; 'GR' release and 'KR' release) and language listeners (2 language listeners; Korean and English listeners) as within-subject factors.

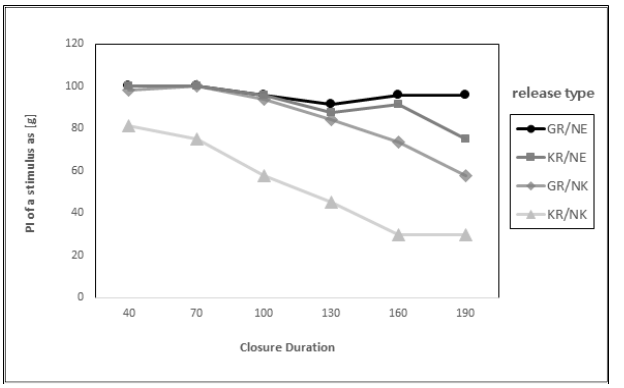

Figure 1. Percent identification of a stimulus as [g] with a long CV

The results for the stimuli, 'long CV' by JU showed that there were significant main effects of release types F(1, 5) = 47.46, p<.002 and language listeners F(1, 5) = 19.59, p<.008, and a significant interaction between release types and language listeners F(1, 5) = 27.02, p<.004. The results were given in Figure 1.

Pairwise comparisons revealed that there was a significant difference between NE listeners and NK listeners when the stimuli had release 'k' (p<.003), but not release 'g' (p>.05). NK listeners showed a significant difference in perception between the stimuli with release 'g' and stimuli with the release 'k' (p<.002). No other differences were observed (p>.05). In short, when presented with various stimuli containing a 'long nag' by Talker JU, NK listeners perceived more [k] for the target when the release was 'k' compared to NE listeners. In other instances, all listeners mostly perceived [g] for the target.

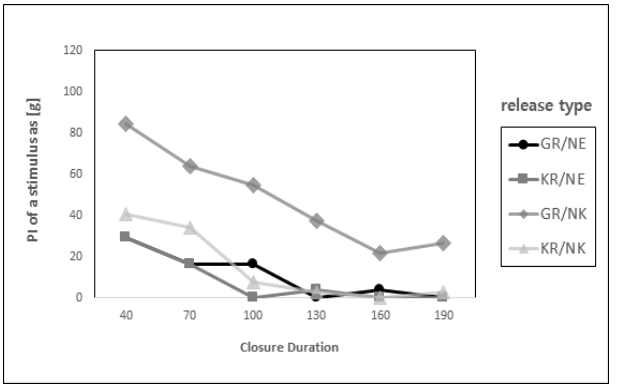

Figure 2. Percent identification of a stimulus as [g] with a short CV

We also examined whether different release types, 'GR' and 'KR', induced different perception results between NK listeners and NE listeners when the stimuli had a short vowel duration, 'short CV' by Talker JU. The correct responses as [g] at each duration interval were submitted to a two-way repeated measures ANOVA with release types and language listeners as within-subject factors. The results for the various 'short CV' stimuli by Talker JU in Figure 2 showed that there were significant main effects of release types F(1, 5) = 34.05, p<.003, language listeners F(1, 5) = 29.76, p<.004, and a significant interaction

between release types and language listeners $F(1, 5) = 61.63$, $p<.002$.

We conducted pairwise comparisons and the results showed that there was a significant difference between NE listeners and NK listeners with release type 'g' ($p<.001$) but not with release type 'k' ($p>.05$). In addition, there was no significant difference between 'g' release type and 'k' release type for NE listeners ($p>.05$) whereas there was a significant difference between 'g' release type and 'k' release type for NK listeners ($p<.002$). In short, NK listeners perceived significantly more [g] than NE listeners did when the final release burst was 'g.' Otherwise, all listeners mostly perceived [k] for the target.

2.2.2. Discussion

The results showed that when the stimuli had a long vowel and the final 'g' release, no perceptual difference between two language listeners occurred in the perception of the target stop. NE listeners and NK listeners mostly perceived [g] from the target. However, if the stimuli had a long vowel and the final 'k' release, NK listeners perceived significantly more [k] compared to NE listeners did from the target stop.

In contrast, when the stimuli had a short vowel, 'short CV,' no perceptual difference occurred between two language listeners if the target stop has final 'k' release. NE listeners and NK listeners mostly perceived [k] from the target. With the final 'g' release, however, NK listeners perceived significantly more [g] compared to NE listeners from the target.

We suggest that the perception difference between two language listeners occurs due to L1 interference. As we discussed in the Introduction, a released stop occurs only at the onset position in Korean and thus, NK listeners would perceive CV from an English word-final released stop, depending on their L2 proficiency. As the target (coda) stop is perceived as an onset, Korean listeners would be sensitive to the VOT, the amplitude of the VOT, its voicing, and the closure duration of this stop as these are the main acoustic cues for the identity of the onset stop in Korean. In contrast, the main acoustic cue for the identity of the word-final stop for NE listeners is the duration of the preceding vowel (cf. Raphel, 1972, etc.). If the preceding vowel is long, the following stop is mostly perceived as a voiced stop whereas if the preceding vowel is short, the following stop is mostly perceived as a voiceless stop.

Thus, from the stimuli of a 'long CV' with the 'k' release, NK listeners perceived more [k] than NE listeners did since voiceless 'k' release was perceived by NK listeners as an onset stop with a long VOT, one of the most salient acoustic cues for a voiceless stop [k]. NE listeners mostly perceived the final stop with 'k' release as a voiced stop [g] due to the preceding long vowel. On the other hand, from the stimuli of a 'long CV' with the 'g' release, NK listeners and NE listeners did not show much difference in the perception of the target stop. The acoustic cue of voiced 'g' release was perceived as a short VOT of an onset [g] by NK listeners.

Different results were obtained when the 'k' release and the 'g' release are attached to a 'short CV.' From the stimuli of a 'short CV' with the 'k' release, no perceptual difference in the perception of the stop occurred between NK listeners and NE listeners. NK listeners and NE listeners mostly have perceived [k] for the target: The coda [k] had relatively long voiceless release burst that was perceived as long VOT for an onset [k] by NK listeners.

From the stimuli of a 'short CV' with the 'g' release, different results between NK listeners and NE listeners occurred. NK listeners perceived more voiced [g] than NE listeners did. Again, we suggest that this is due to L1 interference for Korean listeners. The release burst of voiced [g] is perceived as the short VOT of an onset [g] by Korean listeners, and thus they perceived more [g] for the target than NE listeners did. NE listeners perceived mostly [k] from the 'g' release since the preceding vowel is short.

A few points need to be mentioned. Note that the same 'k' release induced very different perceptual results from NK listeners depending on the CV stimuli: Stimuli of 'long CV' induced more [g] responses from the 'k' release than stimuli of 'short CV' did. One reason may be due to Korean listeners' knowledge of English: They are all university students, having learned English for more than 8-10 years. Another reason may have to do with the closure duration of the stop. Note that the vowel length in the speech determines the rate of the speech. If the preceding vowel is short, listeners will perceive the fast speech rate. As such, the same length of the closure duration of a stop will be perceived as longer than it would be if the preceding vowel is long. Thus, when a stimulus has a short vowel, the following closure duration of a stop will be perceived as long. The long closure duration is an important acoustic cue for the

voiceless stop in Korean. Thus, when the preceding vowel is short, NK listeners would perceive more [k] compared to when the preceding vowel is long..

In short, the experiment in this section showed that L1 interference affected the perception of the released English word-final stop, showing relative effectiveness of the acoustic cues. The release burst of the stop had more influence on Korean listeners than on English listeners as the release burst is perceived as an onset cue to Korean listeners.

2.3. Experiment 2

2.3.1. Results

In this section, we will examine whether the same perceptual results are obtained if the stimuli are from another talker, Talker OR.

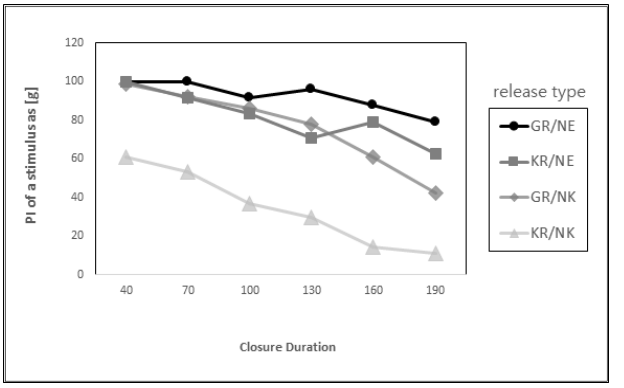

Figure 3. Percent identification of a stimulus as [g] with a long CV

The correct responses as [g] at each duration interval with a 'long CV' were submitted to a two-way repeated measures ANOVA with release types and language listeners as within-subject factors. The results for the stimuli of the 'long CV' in Figure 3 show that there are significant main effects of release types $F(1, 5) = 114.93$ $p<.001$, language listeners $F(1, 5) = 49.51$, $p<.002$, and a significant interaction between release types and language listeners $F(1, 5) = 56.02$, $p<.002$.

Pairwise comparisons show that there was a significant difference in the perception of the stop between NE listeners and NK listeners for release type 'k'

(p<.001), and there was also a significant difference in the perception of the stop between NE listeners and NK listeners for release type 'g' (p<.04). That is, NK listeners perceived significantly less numbers of [g] than NE listeners did when the release type was 'k,' and perceived less numbers of [g] than NE listeners did when the release was 'g.'

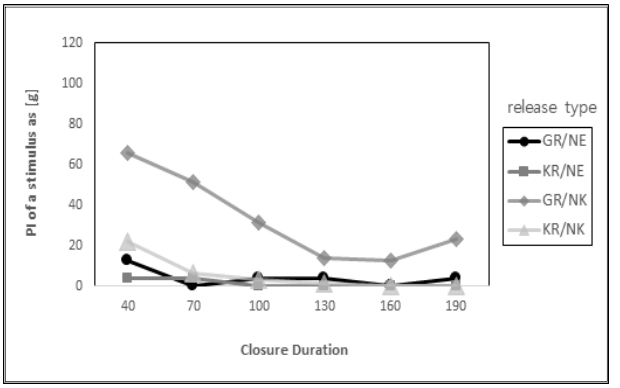

Figure 4. Percent identification of a stimulus as [g] with a short CV

The correct responses as [g] at each duration interval with a 'short CV' were also submitted to a two-way repeated measures ANOVA with release types and language listeners as within-subject factors. The results for the stimuli by OR in Figure 4 showed that there were significant main effects of release types $F(1, 5) = 23.94$ p<.006, language listeners $F(1, 5) = 10.89$, p<.03, and a significant interaction between release types and language listeners $F(1, 5) = 17.75$, p<.009.

Pairwise comparisons show that there was no significant difference in the perception of the stop between NE listeners and NK listeners for release type 'k' (p>.05). For release type 'g,' there was a significant difference in the perception of the stop between NE listeners and NK listeners (p<.02). That is, NK listeners perceived a significantly larger number of [g] than NE listeners did when the release type was 'g,' but there was no significant difference in the perception between NK listeners and NE listeners when the release type was 'k.'

2.3.2. Discussion

When the 'long CV' stimuli with the release 'k' were presented, NE listeners

mostly perceived [g] while NK listeners perceived significantly less numbers of [g] (81% vs. 34% averaged for all duration intervals). This is expected, as the vowel duration is an important acoustic cue in determining the identity of the word-final stop for NE listeners, and thus, long vowel duration mostly induced [g] responses. In contrast, Korean listeners may be more sensitive to the release burst as it is the acoustic cue of the onset consonant. As a result, NK listeners more often perceived a voiceless stop [k] due to the long VOT of [k] than NE listeners did. The results were similar to those with the stimuli of 'long CV' by JU.

When the release was 'g,' both NE and NK listeners mostly perceived 'nag' as Figure 3 shows (average 92% vs. average 76% for closure duration intervals). However, NK listeners perceived somewhat less numbers of [g] compared to NE listeners. In the previous experiment with 'long CV' stimuli by JU, there was no significant difference in the perception of the stop between NE listeners and NK listeners when the release was 'g.' We speculate that this difference occurred possibly due to different acoustic characteristics of the release 'g' by Talker OR from those by Talker JU and relatively longer closure duration of the stop in the stimuli.

Note that the vowel duration for a 'long CV' by OR is far shorter than that by Talker JU (245 ms vs. 355 ms). As such, each closure duration interval of the stop in this experiment would be perceived as longer than the same closure duration interval in the earlier experiment due to the fast speech rate. Thus, NK listeners may have perceived less numbers of [g] than NE listeners did.

The perceptual results with the 'short CV' stimuli also support the conclusion we drew in Section 2.3. When the stop has the 'k' release with the 'short CV,' there was no significant difference in the perception of the stop between NK listeners and NE listeners. They were mostly perceived as [k] for the target. This was expected, as 'k' release had long voiceless release burst that would be perceived as long VOT, an important cue of the voiceless stop [k], by NK listeners. The target stop also had a short vowel duration, an important acoustic cue for the voiceless stop [k] for NE listeners.

When the release was 'g,' NK listeners perceived a larger number of stop [g] than NE listeners did when the stimuli contain a 'short CV.' We suggested earlier that this was due to the different phonological systems of two languages. The target had a short release duration, perceived as short VOT, an important

cue for the voiced stop [g] by NK listeners while it had a short vowel, an important cue for the voiceless stop [k] for NE listeners.

Conclusively, the experiment in this section also showed that relative effectiveness of the acoustic cues prevails in the perception of the English word-final released stop. Burst release and the closure duration of a stop affects Korean listeners more than English listeners in the perception of the released word-final stop.

2.4. Experiment 3

2.4.1. Results

In the previous sections, we showed that Korean listeners were more sensitive to the acoustic characteristics of release bursts than English listeners were in the perception of the released English word-final stop. In this section, we will examine whether four release tokens, two different release bursts of 'g' (weak 'g' release and strong 'g' release) and two different release bursts of 'k' (weak 'k' release and strong 'k' release) with the 'long CV' by talkers JU and OR would induce different perception results from Korean listeners.

The correct responses as [g] at each closure duration for 'long CV' by JU were submitted to a one-way repeated measures ANOVA with four release types as a within-subject factor. The two 'g' release types were referred to as 'g1' and 'g2', and two 'k' release types as 'k1' and 'k2.'

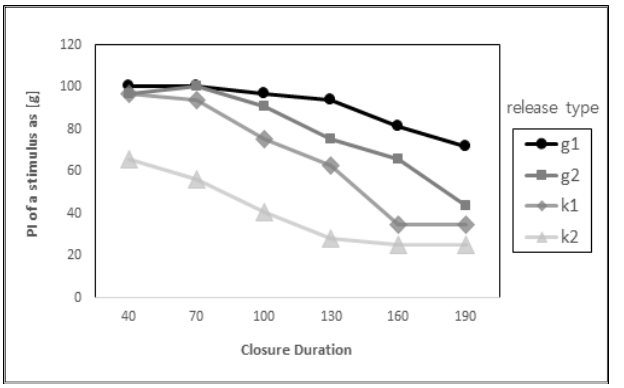

Figure 5. Percent identification of a stimulus as [g] with a long CV by Talker JU

The results for the stimuli 'long nag' of JU by NK listeners showed a significant effect of release types, $F(3, 15) = 35.12$, $p<.001$. Pairwise comparisons showed that there was a significant difference between 'k2' release type from 'g1,' 'g2,' and 'k1' ($p<.002$, $p<.004$ and $p<.03$, respectively). No other significant difference was observed. This shows that Korean listeners distinguish the four release bursts by JU into two categories, one with strong 'k' release, 'k2,' and the other with three releases including two 'g' releases and one weak 'k' release.

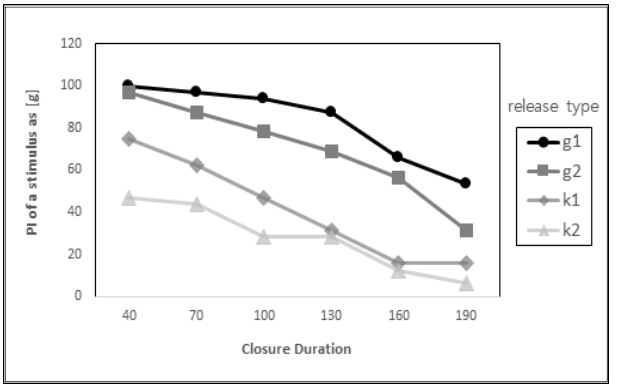

Figure 6. Percent identification of a stimulus as [g] with a long CV by Talker OR

The results for the stimuli of 'long CV' by Talker OR showed a significant effect of release types $F(3, 15) = 93.15$, $p<.001$. Pairwise comparisons showed that there was no significant difference between 'k1' release type from 'k2' ($p>.05$). However, release type 'g1' showed significant difference from 'g2,' 'k1,' and 'k2' ($p<.04$, $p<.003$ and $p<.001$, respectively), and release type 'g2' showed a significant difference from 'g1,' 'k1,' and 'k2' ($p<.04$, $p<.005$ and $p<.002$, respectively). Two variants of release bursts from English phoneme [g] were distinctively perceived, showing three different levels in this case ('g1', 'g2' and 'k1, k2').

2.4.2. Discussion

In English, there are two release categories, 'g' and 'k,' with voicing contrast. This section showed that Korean listeners have grouped these two types of release bursts in various ways depending on the closure duration of the stop

and the preceding vowel length. The acoustic values that separated one phoneme from the other in one language could be differently grouped in another language due to different phonological systems.

3. Conclusion

This paper examined whether the release bursts of English word-final stops was differently perceived due to listeners' different L1 languages. For this purpose, we used the stimuli with different vowel length, the 'long CV' ('long nag') and the 'short CV' ('short nag'), produced by two English native talkers. The 'short nag' was manipulated to approximate the vowel duration of "knack" by cutting out the middle portion of the 'long nag.' These CVs were rejoined with six silent closure duration intervals and two different release tokens of 'g' and two different release tokens of 'k.'

The results showed that when the stimuli of 'long CV' were presented with release 'k,' Korean listeners perceived significantly more [k] compared to English listeners. We suggested that this was due to the different phonological systems of Korean and English. As was well documented, the preceding vowel is the main acoustic cue in the perception of the final released stop by NE listeners. When the preceding vowel was long, NE listeners perceived mostly 'nag' with the final voiced stop with little perceptual influence from the final release 'k.'

In contrast, the released stop in Korean occurs only in the onset position, in which the VOT and the closure duration of the stop are main acoustic cues. Thus, from the voiceless release bursts of the target stop [k], Koreans perceived the long VOT, and thus, more [k] sound than English listeners did.

When the stimuli consist of 'long CV' with release 'g' by Talker JU, NK listeners and NE listeners showed no perceptual difference in the perception of a stop [g]. We suggested that this was due to the phonetic similarities: The acoustic characteristics of release 'g' in the English word-final stop, such as voiced release burst, are not much different from those of [g], namely a short VOT, in the intervocalic position in Korean. With the 'long CV' with release 'g' by Talker OR, NK listeners perceived more [k] than NE listeners did. We have suggested that somewhat longer duration of 'g' release bursts and the relatively

long closure duration may have contributed to more [k] responses by NK listeners.

When the stimuli were 'short CV' with the release 'k,' NE listeners mostly perceived a voiceless stop [k], since the preceding vowel was short. NK listeners mostly perceived a voiceless stop [k] from the same stimuli. We suggested that this was due to L1 interference: Long release duration of 'k' release and the relatively longer closure duration of the stop due to the short preceding vowel induced more [k] responses from NK listeners than from NE listeners.

When the stimuli are 'short CV' with the release 'g,' NE listeners mostly perceived a voiceless stop [k], again due to the short preceding vowel. NK listeners perceived more [g] than NE listeners did since the release 'g' was perceived as an onset, having a short VOT. In short, relative effectiveness of the acoustic cues occurs in the perception of the released English word-final stop due to L1 interference.

This section also showed that the two levels of English release bursts, [g] and [k], could be differently grouped in another language due to different phonological systems.

This paper did not take Korean listeners' proficiency in English into account when we compared NE listeners' responses with those of NK listeners for the identity of the released English word-final stop. We speculate that depending on the proficiency of L2, NK listeners' responses to the released English word-final stop might be quite different. A future study will examine and compare responses of NK listeners who have different L2 English proficiency for the same set of stimuli.

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