The Adaptation of English Word-Medial Coda [ɹ] in Mandarin, Korean and Japanese Loanword Phonology

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1. Introduction

This paper investigates the adaptation of English word-medial coda [ɹ] when English words are borrowed into Standard Mandarin (henceforth, Mandarin), Korean and Japanese. Korean and Japanese have only one phonemic liquid, which is realized as [l] in Korean but disallowed in coda position in Japanese. Mandarin has the phoneme /r/, which is realized as [ɹ] in coda position (Gick et al, 2006). Though [ɹ] can occur in coda in Mandarin, it can only appear in the syllable [əɹ]. Given these facts, when adapting English loanwords, coda [ɹ], if there is any, is almost always problematic and must be fixed. We have found two ways of fixing this segment in this particular position, and they tend to be used in a complementary fashion. Some examples are given in (1):

(1) a. Mandarin: [pʰi.~~əɹ~~.sɨ] *Pie~~r~~ce*, [pu.laj.~~əɹ~~] *Blai~~r~~*, [nʷo.tʷən] *No~~r~~ton*, [kʰa.tʰə] *Ca~~r~~ter*
b. Korean: [ki.~~ə~~] *gea~~r~~*, [pʰe.~~ə~~] *fai~~r~~*, [sɨ.pʰo.tsʰɨ.mæn.sip] *spo~~r~~tsmanship*,
[ma.kʰɛs] *ma~~r~~ket*
c. Japanese: [ka.ʃi.mi.~~a~~] *cashme~~r~~e*, [im.pe.~~a~~.men.to] *impai~~r~~ment*, [~~oː~~.daː] *o~~r~~der*,
[m~~aː~~.ket.to] *ma~~r~~ket*

As we can see in (1), English coda [ɹ] is preserved and turned into a syllable if the preceding vowel is [i] or [e], but deleted if the preceding vowel is [o]/[ɔ] or [ɑ]. To account for these patterns, I adopt the approach that perceptual similarity between input and output determines how an illicit input structure is adapted (Silverman, 1992; Yip, 1993; Steriade 2001a, b; Kang, 2003; Kenstowicz, 2005). Given that in loanword adaptation the output is made as close to the input as possible, a perceptually minimal modification would be preferred over a perceptually non-minimal one. Applying this idea to our case, we can state that the [ɹ] in [iɹ] and [eɹ] is preserved because this modification causes a perceptually smaller change than deleting it, and that the [ɹ] in [oɹ]/[ɔɹ] and [ɑɹ] is deleted because this modification also causes a perceptually smaller change than preserving it. Pushing one more step further, we can hypothesize that, for Mandarin, Korean and Japanese speakers, English coda [ɹ] is perceptually salient when following [i] and [e] but perceptually non-salient when following [o]/[ɔ] and [ɑ] (Steriade, 2001b).

In my data, English coda [ɹ] seems more likely to be preserved in word-final position than in word-medial position. For example, among a total of 19 tokens of English coda [ɹ] following [o]/[ɔ] in the Japanese data base, 16 of them occur word-medially and all of them are deleted, but the other three that occur word-finally are all preserved. I suspect that other factors such as word-final lengthening are also involved in the adaptation if the [ɹ] appears word-finally (Beckman and Edwards, 1987). For this reason, I focus on the adaptation of word-medial coda [ɹ] in this paper.

The rest of this paper is divided into five sections. I give data, generalizations and hypotheses in §2, and discuss in §3 how this context-sensitive idea of perceptual salience can be incorporated into a constraint-based framework such as OT. I provide articulatory and acoustic evidence in support of the hypotheses in §4, and introduce a perceptual experiment that aims to test the hypotheses in §5. The results from the experiment support the hypotheses with the exception of [ɹ] occurring after [o]. I suggest three possibilities regarding this exception. §6 is the conclusion.

2. Data, generalizations and hypotheses

The Mandarin loanword database includes about 2000 English words (mostly proper names), where a total of 397 tokens of word-medial coda [ɹ] violating the Mandarin phonotactics are found. A summary of the data is given in Table 1:

a. Following [i]: 17 tokens
   i. Preserved: 16 tokens/94% (*Pie~~r~~ce* → [pʰi.əɹ.sɨ], *Sea~~r~~s* → [çi.əɹ.sɨ], *Fai~~r~~bank* → [fej.əɹ.pan.kʰə])
   ii. Deleted: 1 tokens/6% (*Goodyea~~r~~* → [ku.tʰə.ji])
b. Following [o]/[ɔ]: 49 tokens
   i. Preserved: 7 tokens/14% (*Co~~r~~bett* → [kʰow.əɹ.pej.tʰə], Horton → [hʷo.əɹ.tʰəŋ])
   ii. Deleted: 42 tokens/86% (*Mo~~r~~gan* → [mʷo.kən], *No~~r~~ton* → [nʷo.tʷən], *Wha~~r~~ton* → [hʷa.tʷən])
c. Following [ɑ]: 87 tokens
   i. Preserved: 7 tokens/8% (*Da~~r~~win* → [ta.əɹ.wən], *Ga~~r~~th* → [tça.əɹ.ʂɨ])
   ii. Deleted: 80 tokens/92% (*Ca~~r~~ter* → [kʰa.tʰə], *La~~r~~sen* → [la.sən], *Sta~~rr~~* → [ʂɨ.tʰa]/[ʂɨ.ta])

Table 1: Summary of the Mandarin data

The Korean loanword data base is based on a survey of the loanword list in the appendix in Kang (2003), which contains 26 English words with at least one instance of coda [ɹ]. A summary of the data is given in Table 2:

a. Following [o]/[ɔ]: 13 tokens
   i. Preserved: 4 tokens/31% (*Nordic* → [no.ɾɨ.tik], *cornet* → [kʰo.ɾɨ.nɛs])
   ii. Deleted: 9 tokens/69% (*warming-up* → [wʌ.miŋ.ʌp], *sportsmanship* → [sɨ.pʰo.tsʰɨ.mæn.sip])
b. Following [ɑ]: 12 tokens
   i. Preserved: 1 token /8% (*marmot* → [ma.ɾɨ.mo.tʰɨ])
   ii. Deleted: 11 tokens/92% (*partnership* → [pʰa.tʰɨ.nʌ.sip], *market* → [ma.kʰɛs])

Table 2: Summary of the Korean data

Though there is no token of [ɹ] that follows a front vowel, the tendency of it being preserved is confirmed by Korean native speakers.[1]

The adaptation of English coda [ɹ] in Japanese is a bit more complicated. In order to make correct generalizations, we first consider Table 3, which shows how English coda [ɹ] following different vowels is adapted without the indication of preservation or deletion. This table is based on a survey of the English loanword list in Mutsukawa (2002).

	Input context	Output realization	Example
a.	Occurring word-medially or -finally and follows [i] or [e]: 4 tokens	[a]	*cashmere* → [ka.ʃi.mi.a] *impairment* → [im.pe.a.men.to]
b.	Occurring word-medially and follows [o]/[ɔ]: 16 tokens	[o]	*corner* → [koː.na(ː)] *north* → [noː.su]
c.	Occurring word-finally and follows [o]/[ɔ]: 3 tokens	[a]	*restore* → [ɾe.su.to.a] *score* → [su.ko.a]
d.	Occurring word-medially and follows [ɑ]: 9 tokens	[a]	*harmony* → [haː.mo.niː] *market* → [maː.ket.to]
e.	Occurring word-finally and follows [ɑ]: 8 tokens	[a]	*star* → [su.taː] *spar* → [su.aː]

Table3: A survey of the English loanword list in Mutsukawa (2002)

At first glance, Japanese speakers seem to preserve English coda [ɹ] and convert it to [a]

[1] Many thanks to Bo Young Kwon and Kyeong Min Park.

unless it occurs word-medially and follows [o]/[ɔ]. Such generalizations are problematic, because the adaptation in (b) would have to be considered exceptional. These "exceptions", however, deserve an account because they are always found in that particular context. Based on what we have observed in the Mandarin and Korean data, I suspect that Japanese speakers actually treat English coda [ɹ] in a similar way. This line of research is what I am going to pursue in this paper. I suggest that in Japanese loanword adaptation, English coda [ɹ] tends to be deleted if it occurs word-medially and follows [o]/[ɔ] or [ɑ], but tends to be preserved and converted to [a] if it follows [i] or [e] or if it occurs word-finally. These generalizations have one advantage: They set a stage for a uniform account for the adaptation occurring in the (b) and (d) contexts. Considering the fact that vowel length is contrastive in Japanese, I assume that Japanese speakers are sensitive to vowel duration when they adapt loanwords. As a result, when Japanese speakers decide that an English coda [ɹ] is not worth preserving and must go, the preceding vowel automatically undergoes compensatory lengthening and surfaces as a long vowel.

Based on this assumption, the Japanese data can be summarized as follows:

a. Following [i] or [e]: 4 tokens/all preserved/100%
b. Following [o]/[ɔ] and appearing word-medially: 16 tokens/all deleted/100%
c. Following [o]/[ɔ] and appearing word-finally: 3 tokens/all preserved/100%
d. Following [ɑ] and appearing word-medially: 9 tokens/all deleted/100%
e. Following [ɑ] and appearing word-finally: 8 tokens/all preserved/100%

Table 4: Summary of the Japanese data

Due to the limited amount of space, this paper focuses on the adaptation of English coda [ɹ] that appears word-medially. Generalizations for the data are given in Table 5:

	Input context	Tendency
a.	Following [i] or [e]	Mandarin: Preserved with [ə] epenthesized before the [ɹ] Korean: Preserved and converted to [ə] Japanese: Preserved and converted to [a]
b.	Following [o]/[ɔ] or [ɑ]	Deleted

Table 5: Generalizations for the data

The working hypotheses for this paper are given in (2):

(2) a. An English word-medial coda [ɹ] is perceptually salient to Mandarin, Korean and Japanese speakers if it follows [i] or [e].

b. An English word-medial coda [ɹ] is perceptually non-salient to Mandarin, Korean and Japanese speakers if it follows [o]/[ɔ] or [ɑ].

3. How does OT deal with context-sensitive salience?

Given that the context can determine the perceptual salience degree of a segment, which in turn can determine whether the segment should be preserved or deleted if it violates the L1 phonotactics, the MAX constraint for a segment should be broken down into several "finer" context-sensitive Max constraints. In addition, the context-sensitive MAX constraints for a segment should have a fixed ranking according to the segment's perceptual salience degrees in various contexts (Steriade 2001a, b). For those segments whose perceptual salience is not greatly influenced by the context (e.g, stridents), there is no need to break the MAX constraints down into several context-sensitive ones. Due to their salient nature, the MAX constraints for these segments should be highly ranked. How this idea is incorporated into the framework of OT is illustrated below:

(3) MAX-[ɹ]/{[i], [e]}__]$_\sigma$: Do not delete [ɹ] if it appears in coda position and follows [i] or [e].

(4) MAX-[ɹ]/{[o], [ɔ], [ɑ]}__]$_\sigma$: Do not delete [ɹ] if it appears in coda position and follows [o], [ɔ] or [ɑ].

(5) DEP-[ə]: Do not insert [ə].

(6) IDENT-[cor]: Correspondent segments in input and output have identical values for [coronal].

Tableau 1: Mandarin: *Fairbank* → [fej.əɹ.pan.kʰə], *Mark* → [ma.kʰə]

Fairbank	MAX-[ɹ]/{[i], [e]}__]$_\sigma$	DEP-[ə]	MAX-[ɹ]/{[o], [ɔ], [ɑ]}__]$_\sigma$
√a. [fej.əɹ.pan.kʰə]		**	
b. [fej.pan.kʰə]	*!	*	
Mark			
√a. [ma.kʰə]		*	*
b. [ma.əɹ.kʰə]		**!	

Tableau 2: Korean: *gear* → [ki.ə], *market* → [ma.kʰɛs][2]

gear	MAX-[ɹ]/{[i], [e]}__]σ	IDENT-[cor]	MAX-[ɹ]/{[o], [ɔ], [ɑ]}__]σ
√a. [ki.ə]		*	
b. [ki]	*!		
market			
√a. [ma.kʰɛs]			*
b. [ma.ə.kʰɛs]		*!	

Tableau 3: Japanese: *impairment* → [im.pe.a.men.to], *north* → [noː.su]

impairment	MAX-[ɹ]/{[i], [e]}__]σ	IDENT-[cor]	MAX-[ɹ]/{[o], [ɔ], [ɑ]}__]σ
√a. [im.pe.a.men.to]		*	
b. [im.peː.men.to]	*!		
north			
√a. [noː.su]			*
b. [no.a.su]		*!	

As we can see above, MAX-[ɹ]/{[i], [e]}__]σ outranks the constraints that would be violated if the [ɹ] is preserved. This is because deleting a coda [ɹ] that appears after [i] or [e] costs more than keeping the [ɹ]'s quality (Korean and Japanese) or inserting [ə] (Mandarin). The constraints that penalize preserving the [ɹ] in turn outrank MAX-[ɹ]/{[o], [ɔ], [ɑ]}__]σ, as deleting a coda [ɹ] that occurs after [o], [ɔ] or [ɑ] is least costly.

4. Phonetics of English coda [ɹ]

The production of [ɹ] involves two articulatory gestures (Delattre and Freeman, 1968; Hagiwara, 1995; Gick, 1999; Gick et al, 2000, 2002; Gick and Campbell, 2003), which, following Gick (1999), are labeled the tongue blade/body raising gesture and the pharyngeal narrowing gesture here. Gick and Campbell (2003) investigated the relative timing of the two gestures of [ɹ] and found that while the pharyngeal narrowing gesture temporally follows the tongue blade/body raising gesture if the [ɹ] is in onset position, a reversed timing pattern occurs if the [ɹ] is in coda position. In addition, Gick et al (2000, 2002) reported a connection between [ɹ] and [ə]: The pharyngeal narrowing gesture of [ɹ] is very similar to the pharyngeal

[2] I simply follow Kenstowicz (2005: Fn 1, p. 7) in assuming that IDENT-[coronal] is the constraint that is violated when English coda [ɹ] is realized as a back vowel.

constriction observed in the production of [ə]. This connection between [ɹ] and [ə] is also confirmed by McMahon (1994, 2000).

These facts give us some clues regarding the perceptual salience of English coda [ɹ] following various vowels. It is known that different vowels involve different tongue positions. When two vowels with similar tongue positions are produced one after the other, the acoustic change created by going from the first vowel to the second vowel would be subtle, as the tongue does not have to move much to reach the position for the second vowel. On the other hand, the acoustic change would be great if the two vowels involve very different tongue positions; that is, to reach the position for the second vowel, the tongue has to travel a relatively long distance. This idea also applies to a sequence such as a vowel followed by a coda [ɹ], as the pharyngeal narrowing gesture of the [ɹ] precedes the tongue tip/blade raising gesture and can be viewed as a schwa. Given that the degree of change in tongue position is correlated with the degree of change in acoustics, which in turn determines the perceptual salience for the second vowel, the perceptual salience of a coda [ɹ] is definitely related to the degree of change in tongue position from the preceding vowel to the schwa component of it.

It is extremely difficult, if possible, to directly measure the change in tongue position between a vowel and a following schwa. However, the change can be inferred from the measurements of the pharyngeal width associated with them. It has been claimed in the literature that the pharyngeal widths associated with vowels are correlated with the vowels' height and frontness. For example, with the aid of MRI, Whalen et al. (1999) measured the midsagittal widths of the air space along the entire vocal tracts of two American English speakers during their production of eleven vowels. A correlation analysis showed that the pharyngeal widths could be predicted from the locations and width measurements for the four spots on the tongue where receiver coils are usually placed in electromagnetometer experiments. MacKay (1977) measured the distance from the external neck wall to the anterior pharyngeal wall during the production of ten English vowels and also found that the measurements are correlated with the vowels' height and frontness.

Vowel	Mean distance	Vowel	Mean distance
i	4.03	æ	4.93
u	4.30	ʊ	5.14
e	4.35	o	5.15
ɪ	4.69	ʌ	5.35
ɛ	4.91	ɑ	5.58

Table 6: The means of the measurements of the distance between the external neck wall and the anterior pharyngeal wall during the articulation of ten English vowels (MacKay 1977)[3] [4]

[3] The higher the value, the narrower the pharyngeal cavity.
4 The distance differs significantly among the vowels ($p<0.001$).

As we can see in this table, a higher vowel always has a smaller mean than a lower vowel with the same degree of frontness, and a front vowel also always has a smaller mean than a back vowel with the same degree of height. These facts indicate that the pharyngeal widths are indeed correlated with the vowels' height and frontness. This table also shows that the two vowels whose means are most approximant to that of [ʌ] are [o] and [ɑ], and that [i] and [e] are among the vowels whose means are least approximant to that of [ʌ].[5] These facts suggest that the tongue position for [ʌ] be most similar to those for [o] and [ɑ] and least similar to those for [i] and [e]. These results strongly support my hypotheses that English coda [ɹ] is perceptually salient after [i] and [e] but non-salient after [o] and [ɑ].

Now we consider the acoustic distance between various vowels and a following coda [ɹ]. We should note that the formant frequencies of English [ɹ] fluctuate depending on its syllabic position. For example, [ɹ] in onset has been found to have much lower formant frequencies than [ɹ] occurring in other positions (Lehiste, 1964; Delattre and Freeman, 1968; Olive, Greenwood & Coleman, 1992). In addition, while the formant frequencies of onset [ɹ] are independent of the following vowel, the formant frequencies of coda [ɹ] seem to depend on the preceding vowel (Lehiste, 1964). For these reasons, the data that are suitable for the present study should be those that can show the formant frequencies of coda [ɹ] following different vowels. Such data are available from Lehiste (1964).

	F1	F2
[i]	250	2150
[e]	400	2000
[ɑ]	700	1100
[ɔ]	550	1000
[o]	400	900

Table 7: The F1 and F2 formant frequencies of five English vowels (Pickett, 1999: 44)

Preceding Vowel	F1	F2
[i]	425	1335
[e]	460	1330
[ɑ]	535	1320
[o], [ɔ]	485	1205

Table 8: The F1 and F2 formant frequencies of coda [ɹ] that follows [i], [e], [o]/[ɔ] and [ɑ] (Lehiste 1964: 62)

5 [ʌ] is very similar to [ə] in nature.

To calculate the acoustic distance between a vowel and a following coda [ɹ], the simplest way is to calculate the distance on each of the two formants and then add the two values up. The results are shown in Table 9:

Sequence	Acoustic Distance
[i ɹ]	990
[e ɹ]	730
[ɑ ɹ]	385
[ɔ ɹ]	270
[o ɹ]	390

Table 9: The acoustic distances between various vowels and a following coda [ɹ]

As we may see in this table, the two larger acoustic distances appear for [iɹ] and [eɹ], and the three smaller ones appear for [ɔɹ], [ɑɹ] and [oɹ]. In addition, there seems to be a gap between these two groups. These facts also support our hypotheses.

Though the articulatory and acoustic evidence is in favor of the hypotheses, it is still considered indirect. In the next section, I will introduce a perceptual experiment which aims to test the relative perceptual salience of the [ɹ] that follow different vowels. The results will tell us whether the adaptation is really a perceptually-based process or not.

5. Perceptual salience of English word-medial coda [ɹ]: A perceptual experiment

5.1 Method

I assume that perceptually, the more/less salient a sound, the more/less salient the contrast between the sound and silence. Since the salience degree of a sound depends on the context, the salience degree of the contrast between the sound and silence would depend on the context as well. Based on this assumption, an experiment was conducted to test the relative perceptual salience of English word-medial coda [ɹ] that follows different vowels. First, I prepared pairs of nonsense disyllabic English words for which the only difference between the two words in each pair lies in whether or not a coda [ɹ] appears in the first syllable (e.g, [hVɹ.gV] vs. [hV.gV]). Four vowels, [i], [e], [o] and [ɑ], were used for the first syllable. The vowel that was used for the first syllable was also used for the second syllable except for the pair of words with [ɑ] in the first syllable, for which I used [i] in the second syllable (i.e. [hiɹ.gi] vs. [hi.gi], [heɹ.ge] vs. [he.ge], [hoɹ.go] vs. [ho.go] but [hɑɹ.gi] vs. [hɑ.gi]). All the words, including those that would serve as fillers, were written down in IPA. A female English native speaker was recruited for the recording. She grew up in the suburb of Chicago and, at the time of the experiment, was a doctoral student in linguistics at Michigan State University. She was asked to read the words in the frame sentence "I say _ twice" at a normal speed in front of a microphone that was attached to a high quality tape recorder. The stress was put on the first syllable. The recording took place in a quiet room.

The tape was digitized into a computer. For each of the 4 test pairs, the rimes of the first syllables of the two words (i.e. [hVɹ] and [hV]) were adjusted using PRAAT until they had the same duration. The stimuli could be classified into three categories: Category I included 8 pairs in the form of [hVɹ.gV] vs. [hV.gV] or [hV.gV] vs. [hVɹ.gV], Category II included 8 pairs in the form of [hVɹ.gV] vs. [hVɹ.gV] or [hV.gV] vs. [hV.gV], and Category III included 48 pairs that would serve as fillers. These pairs were saved as separate sound files with the two words in each pair separated by a one-second period of silence. I next created white noise with PRAAT and had it overlapped with the stimuli. For every sound file, the noise started 0.5 seconds before the first word and ended 0.5 seconds after the second word. I made four copies for each of the sound files classified as Categories I and II, amounting to a total of 112 sound files (16×4+48).

The subjects included 22 Mandarin speakers, 21 Korean speakers, and 22 Japanese speakers. At the time of the experiment, they were between the age of 18–46 and most of them were either college students or graduate students. All of the subjects had learned English as a second language in their home countries for at least 6 years. The period of time they had stayed in the U.S. ranged from a few weeks to 11 years.

The experiment was conducted in a quiet room. The subjects either came alone or as a group no bigger than 6. A brief instruction and a follow-up practice were given before the experiment started. The sound files saved on the computer were played to the subjects in a random order from two speakers which were about 2 meters away from them. The subjects were asked to listen to the stimuli carefully and judge whether the two words in each pair were the same word or not. On the answer sheet, they chose either *same* or *different* for each pair. Each session lasted about 30 minutes.

5.2 Results

The subjects are expected to make more/fewer errors if the [ɹ] in the pair is perceptually less/more salient. The numbers of errors made by the subjects for the pairs in the form of [hVɹ.gV] vs. [hV.gV] thus can represent the relative perceptual salience of the [ɹ] in the context. There are 8 tokens for each test pair (2 orders × 4 copies). For each of the tokens, I gave one point if the subject chose *different* and no point if the subject chose *same*. This means that for each of the four test pairs, the higher/lower the score, the easier/harder for the subject to auditorily discriminate between the two words. The results for the three subject groups are shown in Table 10:

	Mandarin	Korean	Japanese
[i]	7.86	7.86	8.00
[e]	7.82	7.24	7.77
[o]	7.64	7.48	7.00
[ɑ]	4.77	3.71	3.64
Average	7.02	6.57	6.60

Table 10: The mean scores for the four contexts for the three subject groups

As we can see in this table, the mean scores for the [i], [e] and [o] contexts are much higher than that for the [ɑ] context. The fact that the mean scores for the [o] context are high is surprising, as the articulatory and acoustic evidence presented in the previous section implies that a coda [ɹ] following it should be non-salient. This issue will be elaborated later.

An ANOVA analysis was carried out for each of the three subject groups. The results showed that there was a significant difference among the mean scores ($p<.05$) for each group. Multiple comparisons therefore were conducted for each group. The results of the multiple comparisons are identical for the three groups, which are shown in Table 11:

	i	e	o	ɑ
i				*
e				*
o				*
ɑ	*	*	*	

Table 11: The results of multiple comparisons for the Mandarin, Korean and Japanese subject groups (An asterisk mark indicates that the mean scores for the two corresponding contexts are significantly different at a 0.05 confidence level.)

Table 11 shows that each of the mean scores for the [i], [e] and [o] contexts is significantly different from that of the [ɑ] context. The mean scores for the [i], [e] and [o] contexts are not significantly different from each other.

5.3 Discussion

The fact that the mean scores for the [i], [e] and [o] contexts are significantly different from that for the [ɑ] context but not from each other suggests that, for the Mandarin, Korean and Japanese subjects, the word-medial coda [ɹ] exhibits two levels of perceptual salience depending on its context: A high level of perceptual salience when following [i], [e] and [o] and a low level of perceptual salience when following [ɑ]. These results support the hypotheses that English word-medial coda [ɹ] is perceptually salient when following [i] and [e] but non-salient when following [ɑ]. The problem with these results is that the [ɹ] shows a high perceptual salience level when following [o]. There are two possibilities. First, assume that English word-medial coda [ɹ] following [o] is indeed perceptually salient to Mandarin, Korean and Japanese speakers. Lehiste (1964) reported that /o/ is actually realized as [ɔ] before coda [ɹ] in the northern Midwestern dialect of American English. If we further assume that this phenomenon is not limited to this particular dialect but occurs in all dialects of American English, and that word-medial coda [ɹ] is perceptually non-salient when following [ɔ], the contradiction between the loanword data and the results of the experiment has an explanation. That is, the reason that in the loanword data a word-medial coda [ɹ] tends to be deleted if following /o/ is because what Mandarin, Korean and Japanese speakers hear is not the sequence [o]+[ɹ] but the sequence [ɔ]+[ɹ].

The second possibility has to do with the nature of the experiment. Assume that the L1 speaker relies on a threshold of perceptual salience to determine whether an illegal segment (or a legal segment that occurs in an illegal position) should be preserved or deleted. If the salience degree of a segment is below the threshold, preserving the segment would be unworthy and the result would be deletion; otherwise, the segment would be preserved at a minimal cost. Assume that the salience degree of English word-medial coda [ɹ] is below the threshold if the preceding vowel is [o]. The reason that in the experiment it exhibited what we interpreted as a high level of perceptual salience may be because what the subjects were asked to do was to judge whether or not the two words in the pair (e.g, [hoɹ.go] vs. [ho.go]) were the same word. This is to say, though the [ɹ] is below the threshold and not worth preserving, the subject may still be able to auditorily distinguish between the two words, resulting in a false appearance of the [ɹ] being non-salient.

6. Conclusion

Based on the loanword data, I hypothesize that, for Mandarin, Korean and Japanese speakers, English word-medial coda [ɹ] is perceptually salient if it follows [i] or [e] but non-salient if it follows [o]/[ɔ] or [ɑ]. Articulatory and acoustic evidence supports these hypotheses. The results from the perceptual experiment also support these hypotheses except when the [ɹ] occurs after [o]. There are two possibilities for this exception. The first possibility is that English word-medial coda [ɹ] following [o] is perceptually salient to speakers of the three languages, but /o/ in that particular context is realized as [ɔ] in English and coda [ɹ] after [ɔ] is perceptually non-salient to these speakers. The second possibility is that the results from the experiment fail to represent the non-salient nature of the [ɹ].

References

Beckman, Mary and Jan Edwards (1987). The Phonological Domains of Final Lengthening. *Ohio State University Working Papers in Linguistics* 35: 167-176.

Delattre, P. and D. C. Freeman (1968). A Dialect Study of American R's by X-Ray Motion Picture. *Linguistics* 44. 29-68.

Gick, Bryan. (1999). A gesture-based account of intrusive consonants in English. *Phonology* 16. 29-54.

Gick, B., A. M. Kang and D. H. Whalen (2000). MRI and X-Ray Evidence for Commonality in the Dorsal Articulations of English Vowels and Liquids. *Proceedings of the 5th Seminar on Speech Production: Models and Data and the Crest Workshop on Models of Speech Production: Motor Planning and Articulatory Modeling*. Kloster Seeon, Bavaria, Germany.

Gick, B., A. M. Kang & D. H. Whalen (2002). MRI Evidence for Commonality in the Post-Oral Articulations of English Vowels and Liquids. *Journal of Phonetics* 30. 357-371.

Hagiwara, Robert (1995). Acoustic Realizations of American /r/ as Produced by Women and Men. *University of California Working Papers in Phonetics* 90. 1-187.

Kang, Yoonjung (2003). Perceptual similarity in loanword adaptation: English postvocalic word-final stops in Korean. *Phonology* 20. 219-273.

Kenstowicz, Michael (2005). The phonetics and phonology of Korean loanword adaptation. To appear in S-J. Rhee (ed.) *Proceedings of First European Conference on Korean Linguistics*.

Lehiste, Ilse (1964). Acoustical Characteristics of selected English consonants. *International Journal of American Linguistics* 30 No. 3 Part IV. Indiana University Research Center in Anthropology, Folklore, and Linguistics.

MacKay, I. R. A. (1977). Tenseness in Vowels: an Ultrasonic Study. *Phonetica* 34. 325-351.

McMahon, April (1996). On the Use of the Past to Explain the Present: The History of /r/ in English and Scots. In Britton, Derek (ed) *the 8th International Conference on English Historical Linguistics*. 73-89.

McMahon, April (2000). *Lexical phonology and the history of English*. Cambridge, New York: Cambridge University Press.

Mutsukawa, Masahiko (2002). *The realization of (r) in English-based loanwords in Japanese: an optimality-theoretic analysis*. MA Thesis, Michgan State University.

Olive, Joseph, Alice Greenwood and John Coleman (1993). *Acoustics of American English Speech: A Dynamic Approach*. Springer Verlag.

Pickett, J. M. (1999). *The Acoustics of Speech Communication: Fundamentals, Speech Perception Theory, and Technology*. Prentice Hall.

Silverman, Daniel (1992). Multiple Scansions in Loanword Phonology: Evidence from Cantonese. *Phonology* 9. 289-328.

Steriade, Donca (2001a). Directional asymmetries in place assimilation: A perceptual account. In Elizabeth V. Hume and Keith Johnson (eds.) *The Role of Speech Perception in Phonology*, 219-249. San Diego: Academic Press.

Steriade, Donca (2001b). The Phonology of Perceptibility Effects: the P-map and its Consequences for Constraint Organization. Ms., UCLA.

Whalen, D. H., A. M. Kang, H. S. Magen, R. K. Fulbright and J. C. Gore (1999). Predicting Midsagittal Pharynx Shape from Tongue Position during Vowel Production. *Journal of Speech, Language, and Hearing Research* 42. 592-603.

Yip, Moira (1993). Cantonese Loanword Phonology and Optimality Theory. *Journal of East Asian Linguistics* 2. 261-291.

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