Place Perception in Korean Consonants*

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ABSTRACT

Place assimilation in Korean has been argued to reflect the consonantal strength hierarchy in which velar is stronger than labial which is in turn stronger than coronal. The strength relationship has been manifested in two ways in literature. One is through phonological representation as shown in Iverson and Lee (1994). The other is through perceptual salience ranking as suggested by Jun (1995).

The goal of this study is to examine the perceptual salience of placed consonants through an identification experiment. The experiment conducted in this study reveals four facts. First, place identification of a prevocalic consonant is higher than that of a postvocalic one. Second, place identification of a stop in coda is more confusable than that of a nasal counterpart in Korean contrary to other previous studies. Third, velar is most confusable in place identification in contrast to Jun (1995) and Hume et al. (1999). Finally, place perception of consonants can vary depending on adjacent vocalic context. These results suggest that perceptual salience is one of the possibly several factors affecting a phonological process.

Keywords: Place Assimilation, Consonantal Strength, Perceptual Salience, Place Perception, Confusability

1. Introduction

Place assimilation in Korean is illustrated in (1) and (2).

(1) a.	/pat−ko/	[pakk'o][1)]	'receive and'
	/pat^{h}−pota/	[papp'oda]	'rather than a field'

* I thank two anonymous reviewers for their valuable comments and suggestions. All errors are my own responsibility.

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b. /pap−kwa/	[pakk'wa]		'rice and'
/pap−to/	[papt'o]	*[patt'o]	'rice also'
c. /pak'−pota/	[pakp'oda]	*[papp'oda]	'rather than outside'
/pak'−to/	[pakt'o]	*[patt'o][1]	'outside also'
(2) a. /sin−ko/	[siŋk'o]		'put on shoes and'
/sin−pota/	[simboda]		'rather than shoes'
b. /sam−kwa/	[saŋgwa]		'three and'
/sam−to/	[samdo]	*[sando]	'three also'
c. /saŋ−to/	[saŋdo]	*[sando]	'table also'
/saŋ−pota/	[saŋboda]	*[samboda]	'rather than a table'

Coronal stops and nasals assimilate in place to a following labial or dorsal consonant as in (1a) and (2a). Labial stops and nasals, on the other hand, assimilate in place to dorsal but not coronal consonants as shown in (1b) and (2b). Dorsal stops and nasals do not assimilate to either a following coronal or labial as in (1c) and (2c).[1)]

Iverson and Lee (1994) assume the hierarchy in (3) for Korean place assimilation on the basis of phonological markedness expressed by the feature hierarchy: the more marked the segment, the greater the amount of representational structure.

(3) dorsal > labial > coronal

On the other hand, Jun (1995) and Steriade (2001) view assimilation as a perceptually motivated process. They contend that contrast is maintained when enough perceptual cues are given but the absence of a major perceptual cue is mainly responsible for assimilation. Jun (1995) proposes the universal salience ranking in (4) based on the acoustic hierarchy for unreleased stop consonants.

(4) Perceptual salience: dorsal > labial > coronal

Greater perceptual salience is assumed to be a result of more robust cues and a better cue package. Then the ranking in (4) suggests that the acoustic cues for the unreleased coronal are weaker than those for the unreleased labial which are in turn

1) The outputs include forms derived by a regular process of Korean coda neutralization in which underlying tense and aspirated coda consonants are neutralized to their unreleased lenis counterparts in syllable−final position.

weaker than those for the unreleased dorsal. Jun (1995) maintains that tongue tip gestures are rapid; thus, they have short transition cues. In contrast, tongue dorsum and lip gestures are more sluggish; thus, they have long transitions. Consequently, noncoronals have more robust perceptual cues than coronals.

Phonological markedness appears to be directly related to perceptual salience. However, Jun's (1995) analysis of perceptual salience is based on speculation and not experimentation. It seems fair enough to ask if these conclusions are really valid through a perception experiment. On the other hand, Hume et al. (1999) investigate direct test of the salience ranking in (4) by comparing the perceptual salience of place of articulation by Korean listeners and American listeners. The stimuli were composed of release bursts and transition portions of /p^h/, /t^h/, and /k^h/ into three different vowels (/i/, /a/, /u/). Their findings comply with Jun's (1995) suggestion in that the average sensitivity showed dorsal to be highest in salience, followed by labial and coronal mainly due to the transitions. The tested stops in their stimuli were released in the onset. However, the undergoers of place assimilation in Korean are not released in the coda: In the consonant cluster C_1C_2, C_1 is unreleased.

Steriade (1999) contends that nasals are more confusable than stops, which in turn are more confusable than fricatives in place perception following Hura et al. (1992). Hura et al. (1992) carried out perception tests to compare English fricatives, stops and nasals in confusability when occurring before a stop. However, no study has ever been done concerning the relative perceptibility of place distinctions between nasals and stops in coda position in Korean. The same pattern between nasals and stops in place assimilation as illustrated in (1) and (2) suggests the same perceptual salience ranking with respect to place of articulation for both stops and nasals.

The goals of this paper are to test perceptual salience of the nasal and stop in coda and to test perceptual ranking of unreleased stops and nasals with respect to place of articulation through an identification test by Korean listeners.

2. The Experiment

The stimuli were taken from a recording of one phonetically untrained female native speaker of Seoul Korean. Recordings were made in a sound-attenuated booth at Yeojoo Institute of Technology. Each syllable, which consists of a plain stop or nasal (/p, t, k, m, n/) and following vowel (/a, i, u/), and of a vowel (/a, i, u/) and following plain stop or

nasal (/p, t, k, m, n, ŋ/),[2] was presented to the speaker in Korean orthography in random order: A plain stop and nasal were placed either in the onset or in the coda. Each syllable was recorded three times. In total, 99 syllables (((5 onset consonants X 3 vowels) + (3 vowels X 6 coda consonants)) X 3 repetitions) were used as the stimuli.

The listeners were 48 native speakers of Seoul Korean (23 males, 25 females). They were all students at Yeojoo Institute of Technology. None of them had any known speech or hearing disorders. The age range for them was 20 to 28 years. Listeners were instructed by the experimenter to listen carefully to the stimuli through headphones to three repetitions of the same token and then select the syllable that they thought they heard by circling the syllable in the test paper. The test paper contained three different printed syllables (two different printed syllables for the NV syllable), written in Korean, for each stimulus, i.e., pa, ta, ka; pi, ti, ki; pu, tu, ku; ma, na; mi, ni; mu, nu; ap, at, ak; ip, it, ik; up, ut, uk; am, an, aŋ; im, in, iŋ; um, un, uŋ. Listeners heard each syllable once with a two-second response-to-stimulus interval.

3. Results and Discussion

I counted the number of times when the target consonant was misidentified by subjects to find the degree of confusability. Tables 1 and 2 show the results of misidentification by females and males, respectively.

Table 1. Confusability of consonants in different prosodic positions for 25 females (C stands for /p, t, k/ and N for /m, n/ in the onset and for /m, n, ŋ/ in the coda).

Segmental sequence		Numbers of misidentification
Onset position	Ca	0/225
	Ci	0/225
	Cu	0/225
	Na	1/150
	Ni	20/150
	Nu	0/150
Coda position	AC	7/225
	IC	27/225
	UC	32/225
	AN	0/225
	IN	1/225
	UN	5/225

2) /ŋ/ cannot appear in the onset but in the coda.

Table 2. Confusability of consonants in different prosodic positions for 23 males (C stands for /p, t, k/ and N for /m, n/ in the onset and for /m, n, ŋ/ in the coda).

Segmental sequence		Numbers of misidentification
Onset position	Ca	2/207
	Ci	2/207
	Cu	0/207
	Na	0/98
	Ni	31/98
	Nu	3/98
Coda position	AC	15/207
	IC	31/207
	UC	38/207
	AN	2/207
	IN	6/207
	UN	5/207

The values in Tables 1 and 2 indicate the number of tokens idenified by the subjects as involving another consonant rather than a target consonant out of a total number of tokens. A few facts are apparent from these figures. First, place identification of a consonant is higher in onset than in coda. Second, the misidentification of /Ni/ is noticeable. Third, the point of articulation of a stop in coda is more confusable than that of a nasal counterpart. These three points will be discussed in the order.

It is not surprising that the place of a stop is more easily identified before a vowel than after a vowel. Stop release bursts are a prominent place cue (Malécot 1958) and all else being equal, consonants before vowels are more perceptible than consonants after vowels. And thus CV transitions provide better cues than VC transitions (Fujimura et al. 1978). Thus the result verifies Jun's least controversial hypothesis: Position: Pres(pl(onset)) >> Pres(pl(coda)). The second fact attests the interaction between the identification of place of articulation and an adjacent vowel: all misidentification of /Ni/ comes from /ni/ as [mi] misidentification. That indicates that perception of the place of articulation of a nasal depends on the following vocalic quality. Two tokens of misidentification of /Nu/ also result from /mu/ as [nu] misidentification in Table 2. In other words, /n/ and /m/ tend to be misperceived when preceded by a front vowel and a labial vowel, respectively. The third fact needs our attention. Nasals' confusability has been shown to be higher compared to stops by Fant (1968) and Mohr and Wang (1968). Jun (1995) also contends that unreleased nasals have weaker place cues than unreleased stops. The results in Tables 1 and 2 are at odds with these previous studies. Steriade (pc) suggests that the result may result from the different realization of the vowel preceding a nasal between English and Korean. Jun, Sun-Ah (pc) observes that

the degree of vowel nasalization before a nasal is weaker for Korean VN than for English VN. Weakly nasalized vowels could carry more place cues than strongly nasalized vowels. But regardless of the degree of nasalization, VN place cues would be easier to perceive than VC place cues because the place cue is heard during the duration of nasals but not for stops whose cues are only heard in stop implosion and release. In other words, the different result from the previous studies may have to do with the fact that stops are never released in coda in Korean as opposed to in English.[3] On the other hand, Winters's (2002) experiment based on English speakers' perception also attests that nasals are more salient than stops in coda. Then, for some reason not apparent in the acoustic signal, listeners actually seem to be more sensitive to place information in nasals than in oral stops in coda position.

Tables 1 and 2 do not show the confusablility regarding different places of consonants. From now on, we will focus on place identification of a consonant in coda as opposed to in onset since the consonant in coda exclusively undergoes place assimilation. Tables 3 and 4 show the confusability results with respect to place of articulation of the coda consonants.

Table 3. Place confusability of consonants for 25 female listeners

Segmental sequence	Numbers of misidentification
Vp	21/225
Vt	16/225
Vk	29/225

Table 4. Place confusability of consonants for 23 male listeners

Segmental sequence	Numbers of misidentification
Vp	19/207
Vt	22/207
Vk	43/207

T-tests between p/t, t/k, and p/k are shown in Table 5.

3) I thank Donca Steriade and Sun-Ah Jun for their comments on this unexpected result.

Table 5. T-test results for place confusability[4)]

Consonants	Female (T-test)	Male(T-test)
p/t	p<0.05 *	p>0.05
t/k	p<0.001 *	p<0.001 *
p/k	p<0.005 *	p<0.001 *

Following Steriade's (2001) contention that the direction of assimilation is determined by the relative perceptibility of place distinctions, we would expect that unreleased velar is more salient than the unreleased labial which is in turn more salient than the unreleased coronal based on the data in (1) and (2). Contrary to the assumption that more salient sound is less confusable, Tables 3-5 show that the relative sensitivity of unreleased place in coda position contradicts Jun's (1995) assumption in (4). That is to say, the degree of confusability in a dorsal consonant is rather higher than in a coronal or labial consonant. Dorsal is most confusable in place identification in coda. Lisker's (1999) experimental results are, on the other hand, in line with the results of this paper. He also observes that unreleased dorsal is least perceived among unreleased stops.[5)]

Then the question is why /k/ in the coda is in fact least susceptible to place assimilation and /kk/ is preferred to /tk, pk/? One possible answer can be found in an articulatory account. Hume (2001) argues that the articulation of the first consonant be posterior to that of the second. The rationale behind this argument has to do with the aerodynamics of egressive airflow: ordering the articulations in a manner consistent with the direction of airflow may provide greater air pressure for the production of the release bursts in stops. Thus the culsters, /kp, kt/ are preferred to /pp, tt/ blocking place assimilation. Then we can say that /k/ does not undergo place assimilation to the following consonant not due to perceptual saliency but due to articulatory motivation. In fact, Jun (1995) found air rarefaction in [pk] sequence (and less so in [tk] sequence) for Korean CC sequence. The release burst of C_2 in C_1C_2 would be much weaker if the place of articulation is front-back sequence. For this aerodynamic argument to work, we have to say that the clusters, [kp, kt] are preferred to [pk, tk]. And, the clusters, [pk, tk] may be less preferred to [kk] geminate. But, this articulatory account cannot explain why /tp/ becomes [pp] as in (1a). The cluster, /tp/ should be intact since it is the back-

4) One reviewer points out that females and males exhibit different confusability between /p/ and /t/. I do not have any possible explanation at hand.

5) I am grateful to one reviewer for introducing Lisker's (1999) paper on perception of unreleased stops.

front sequence. Thus, the articulatory account as well as the perceptual saliency of the coda stop cannot satisfactorily provide the motivation for place assimilation in Korean.

Higher rate of correct identification of /t/ may come from the high frequency of t-ending words (Steriade pc). In Korean, coda /t, t^h, s, s', h, c, c^h/ are neutralized to [t]. In order to lessen the frequency effect, we may add the confidence level by asking the subjects how confidently they are answering (Jun, Sun-Ah pc). Then we can find the extent to which the correct identification came from random choice.

Jun (1995) notes that preservation of perceptual cues for a prepausal coda is more highly ranked than that for a coda followed by another consonant: Pres (pl___%) >> Pres (pl___C). The target consonants employed by this experiment are prevocalic or prepausal. The results of place confusability suggest that place assimilation does not have to do with the perceptual cues of C_1 by itself but with the sequence of C_1C_2: the perceptual cues are different between when there is only one coda consonant and when there are two placed consonants. A coda followed by another consonant has acoustically weaker place cues due to the overlap with C_2 than a prepausal coda. As already argued by Jun (1995), the acoustic salience of place cues for the first constituent of a consonant cluster can vary depending on the place of the following consonant. In the sequence $V_1C_1C_2$, the formant transitions of V_1 are affected by both C_1 and C_2 as shown by Byrd (1992), although C_1 is usually stronger than C_2. Jun (1995) maintains that in a consonant cluster C_1C_2, the degree of obscuring place cues for C_1 depends on the inherent velocity of C_2 articulators. More specifically, a slower movement obscures place cues of a neighboring gesture more. Byrd (1992) assumes that "a slower movement might prove more difficult to hide," following Browman and Goldstein (1992). Jun (1995) assumes that coronals are characterized by rapid movements, whereas noncoronals by slow movements. From this, it follows that the place cues of C_1 can be obscured more easily before noncoronals than coronals. He, thus, argues for the universal ranking for trigger places as in (5).

(5) Pres (pl(___cor)) >> Pres (pl(___noncor))

Jun's argument that place cues of a consonant must be preserved before coronals in preference to before noncoronals is based on the velocity of the articulators of C_1C_2. However, it needs more investigation since labials are not likely to have slow movements contrary to his argument (Jun, Sun-Ah pc).

Next, we will examine place confusability in various vocalic contexts. Tables 6 and 7 show that coda stop confusability is sensitive to the preceding vowel.

Table 6. Females

Segmental sequence		Number of misidentification
Vp	ap	1/75
	ip	9/75
	up	11/75
Vt	at	3/75
	it	9/75
	ut	4/75
Vk	ak	3/75
	ik	9/75
	uk	17/75

Table 7. Males

Segmental sequence		Number of misidentification
Vp	ap	2/69
	ip	6/69
	up	11/69
Vt	at	7/69
	it	13/69
	ut	2/69
Vk	ak	6/69
	ik	12/69
	uk	25/69

Tables 3 and 6, and 4 and 7 are different classifications of the same results: the first table is classified by the sequence of a target consonant and any vowel, the second by a target consonant in a specific vowel context.

Tables 6 and 7 illustrate the interaction between vowel type and place perception of consonants: labial and dorsal are most confusable after /u/, while coronal is most confusable after /i/. Likewise, consonants are more confusable when adjacent to a vowel, which is similar in place of articulation. Hume et al. (1999) show that the relative salience of place cues, particularly those for dorsal, is highly dependent on the neighboring vowel. The salience of the burst and transition cues for the dorsal, /k/, is dependent on the identity of the following vowel and in back vowel environments /k/ is more salient than /p/ or /t/. Notice that their results are based on the place identification in onset. However, the undergoer of place assimilation is in coda. Tables 6 and 7 show that the dorsal stop in coda is most confusable in place after /u/. Unreleased stops lack the prominent place cues in the burst and formant transitions out of the preceding vowel are the only available place cues for these stops. In general, tongue dorsum sound (/k/)

shows slower formant transition than dental or bilabial. If the vowel is short as a high vowel, this difference may not be salient and cause high confusability. Notice that the place of articulation of dorsal is more easily perceived after /a/ which is longer in duration than /u, i/. The higher confusability after /u/ than after /i/ may have to do with tongue position. Perceptual cue for dorsal after a back vowel is less robust than after a front vowel. By the same token, perceptual cue for coronal after a front vowel is less robust than after a back vowel. Another case of the interaction between vowel type and perception of place of articulation has been attested by /ni/. Tables 1 and 2 show the higher misidentification in Ni than Na or Nu. To be more exact, all misidentifications come from /ni/.

4. Conclusions

There have been two alternatives for the account for place assimilation in Korean. One is the phonological representation approach (Iverson and Lee 1994) and the other is the perceptual approach (Jun 1995). This study investigated perceptual saliency of placed consonants in coda to test Jun's (1995) hypothesis for place assimilation in Korean through an identification experiment.

Results of this study revealed four facts. First, place identification of a prevocalic consonant is higher than that of a postvocalic one. Second, place identification of a stop in coda is more confusable than that of a nasal counterpart in Korean contrary to other previous studies. Third, dorsal is most confusable in place identification. This finding is not in line with Jun (1995) and Hume et al. (1999) but in line with Lisker (1999). Two possible accounts have been considered for this result: the articulatory account and the different place cue account between the consonant cluster and a singleton. This indicates that perceptual salience is one of the possibly several factors influencing a phonological process. Finally, perceptual salience of consonantal place depends on adjacent vocalic environment. Place of consonants tends to be identified better when the consonants in interest contrast with an adjacent vowel in place.

This study only dealt with the data with a single consonant in the onset or in the coda. Place assimilation takes place when consonants with different place of articulation are put together. Then future work is needed to investigate the perceptual cues for consonant place of articulation in the appropriate (VCCV) context for place assimilation.

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