Phonetic Functionalism in Coronal/Non-coronal Asymmetry*

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ABSTRACT

Coronal/non-coronal asymmetry refers to the typological trend wherein coronals rather than non-coronals are more likely targets in place assimilation. Although the phenomenon has been accounted for by resorting to the notion of unmarkedness in formalistic approaches to sound patterns, the examination of rules and representations cannot answer why there should be such a process in the first place. Furthermore, the motivation of coronal/non-coronal asymmetry has remained controversial to date even in the field of phonetics.

The present study investigated the listeners' perception of coronal and non-coronal stops in the context of VC_1C_2V after critically reviewing the three types of phonetic accounts for coronal/non-coronal asymmetry, i.e., articulatory, perceptual, and gestural overlap accounts. An experiment was conducted to test whether the phenomenon in question may occur, given the listeners' lack of perceptual ability to identify weaker place cues in VC transitions as argued by Ohala (1990), i.e., coronals have weak place cues that cause listeners' misperception. Spliced nonsense VC_1C_2V utterances were given to 20 native speakers of English and Korean. Data analysis showed that majority of the subjects reported C_2 as C_1. More importantly, the place of articulation of C1 did not affect the listeners' identification. Compared to non-coronals, coronals did not show a significantly lower rate of correct identifications. This study challenges the view that coronal/non-coronal asymmetry is attributable to the weak place cues of coronals, providing evidence that CV cues are more perceptually salient than VC cues. While perceptual saliency account may explain the frequent occurrence of regressive assimilation across languages, it cannot be extended to coronal/non-coronal asymmetry.

Keywords: Coronals, Perceptual Saliency, Weak Place Cues

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1. Introduction***

The purpose of the present study is to examine a phonetic explanation for a phonological pattern frequently found in human languages. The phonological pattern in question is the behaviors of coronals in place assimilation. There are several strong tendencies in place assimilation across languages (Mohanan 1993). One of the tendencies is the coronal/non-coronal asymmetry: coronal consonants are more likely targets than non-coronals. Namely, coronals are more likely to assimilate to the place of articulation of the following consonant than non-coronals (Kenstowicz, 1993; Mohanan, 1993; Ohala, 1990 among others).

Non-linear phonology attributes this coronal/non-coronal asymmetry to the postulated geometry of articulatory features and the notion of spreading assuming that coronals are the most unmarked sound in human languages. Similarly, Optimality Theory also relies on the notion of markedness. Smolensky (1994) argues that marked segments are phonologically active, and unmarked ones are phonologically passive. Consequently, the less marked a segment is, the less likely it is to be the target of assimilation. This claim seems to provide a good account for why the syllable-final neutralization of place favors coronals rather than dorsals or labials; coronals are unmarked and thus phonologically passive. If we apply the same reasoning of markedness notion to place assimilation, it is predicted that coronal consonants should be the most unlikely target of the assimilation, which is not the case in most languages. More importantly, such attempts based on the notion of markedness might be descriptively adequate but they do not explain why coronal/non-coronal asymmetry frequently occurs in human languages in the first place.

As readers might have noticed, the issue addressed above is related to the issue of formalism and functionalism in dealing with sound patterns. This paper is based on the perspective that all the cross-linguistically common phonological patterns reflect phonetic patterns (Lindblom 1983; Ohala 1983; Archangeli and Pulleyblank 1994). We may refer this view as 'phonetic functionalism.

Despite the consensus that coronals are the more likely targets in place assimilation, not many studies have asked to answer the following questions: Why do coronals show such special behavior especially with respect to place assimilation? What is the phonetic

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explanation or reason for such phonological patterns? Is it due to articulatory or perceptual motivations? This paper tries to answer those questions by looking at the phonetic grounds for coronal place assimilation.

This paper is organized in the following way: Section 2 critically reviews the previous accounts of the motivation of the place assimilation. Section 3 presents an experiment that investigates listeners' perception of coronal and non-coronals stops. Section 4 provides some concluding remarks.

2. Possible Motivations of Coronal/Non-coronal Asymmetry in Place Assimilation

2.1 Articulatory account: Ease of articulation

The most common and classical explanation given for coronal/non-coronal asymmetry in place assimilation is that it is due to ease of articulation, i.e., that the speaker opts for an articulation that is easier or simpler than the original for the economy of speech (Ohala, 1990). Even though the idea of 'ease of articulation' has been refuted by some linguists because i) it cannot be measured, ii) it is language specific, and iii) it is teleological (Ohala, 1990; Ladefoged, 1990), there have been attempts to measure articulatory difficulty of sounds. Willerman (1994) is one of such studies.

According to Willerman, articulatory difficulty depends on three factors: (i) the amount of biomechanical works required, (ii) the number of articulators (or articulatory channels) involved, and (iii) the precision and the complexity of control required. Thus, the greater the number of articulatory channel activated for a particular sound is, and the greater the degree of spatial precision and temporal precision required, the greater the difficulty and the complexity of the given articulation. As for precision, three stops [t], [p], and [k] are equal in their difficulties, since stops do not require great articulatory precision in general (Stevens, 1971). With regard to (ii), both [p] and [k] have an additional articulatory channel compared with [t]: the mandible. Adding mandibular gesture, however, does not increase difficulty since consonants usually combine with vowels, which require mandibular gesture for articulation. The main difference among the three stops lies in the biomechanical work required.

There have been some studies to measure the required biomechanical work based on the articulator velocity (Kuehn and Moll, 1976).[1] The basic assumption in these studies is that the higher the velocity of a given articulator, the smaller the biomechanical work required to articulate the sounds. What is commonly found in these studies is that the tongue tip moves faster and farther than the tongue body and the lower lip, which means [t] is easier to produce and to control than [p] and [k].

These studies make it clear that coronal stops are the easier sound to produce and control. From the above studies, one might jump to the conclusion that coronals are more likely targets in place assimilation since speakers need to resort to the easiest articulator, tongue tip, for the economy of speech effort. However, this sort of reasoning is incompatible with coronal place assimilation in two respects. First, the ease of articulation account does not explain why speakers make the utterance more difficult to produce by assimilating coronals to non-coronals. Second, the ease of articulation account does not account for why C_1 assimilates to C_2 in VC_1C_2V contexts. Since the energy expanded in production presumably accumulates from the beginning, there would be greater motivation in the later part of an utterance to resort to less effortful articulation for economy of articulatory effort. Yet it is usually C_1, the earlier segment that assimilates to later C_2 not vice versa.

In sum, the 'ease of articulation' account predicts that non-coronal sounds should assimilate to coronals, making a given utterance simpler and easier, and that C_2 should assimilate to C_1 in VC_1C_2V contexts. If so, non-coronals rather than coronals are predicted to be more likely targets in place assimilation according to the ease of articulation account, which is not the case. Therefore, it seems that the ease of articulation account does not provide an answer for the motivation of the coronal/non-coronal asymmetry in place assimilation.

2.2 Perceptual account

2.2.1. Assimilation due to perceptual saliency and weak place cues

It has been noted that assimilation normally affects sounds that are already very similar (Hutchinson, 1973; Kiparsky, 1988) even though it has not been well-defined how and in what way they should be similar. Perceptual accounts interpret this 'similarity' in

1) Kuehn and Moll (1976) found in cineradiographic studies of articulatory velocity that tongue tip movements have higher velocities than either tongue dorsum or lip movements: tongue tip (196 mm/s), lower lip (166 mm/s) and tongue dorsum (129 mm/s) in both coordinated (maximally and mandibular) systems.

terms of similarity in perception. In German casual speech, only coronal consonants such as /t/, /d/ and /n/ are apt to assimilate to following stops, while labial, velar stops and fricatives do not participate in the assimilation. Kohler (1990:88) accounts for this in terms of perceptual distinctiveness. He stated that "fricatives especially sibilants are not assimilated because they are far more distinct than nasal and stops with regard to place cue." Hura, Lindblom and Diehl (1992) also support that it is significantly easier to discriminate among fricatives than among nasals. What is common in the two studies is that perceptual saliency plays an important role in assimilation.

Let us have a close look at Hura, Lindblom and Diehl (1992). Using a tape-splicing technique, they measured subjects' correct identification rate for nasals, stops, and fricative at various places of articulation and examined the types of errors made by subjects. As stimuli, they used two-word human names such as Shanim Kerry, Shanin Perry, Shanif Perry, etc. Subjects were asked to identify the last consonant in the first name of each pair. They found that subjects made significantly more errors in the identification of nasals than in the identification of fricatives. They explained that this is due to the weak place cues of nasal.[2)]

What Hura et al. (1992) argues is that assimilation is the function of perceptual factors, rather than articluaratory factors. They argue that phonological pattern such as nasal place assimilation is motivated by listeners' frequent misidentification due to the weak place cues of nasals. Namely misperception affected phonological patterns. Hura et al. (1992) appears to provide a good account for why nasals assimilate to the place of articulation of the following consonants. However, their account seems to be inappropriate for the coronal/non-coronal asymmetry. As their account is focused on the different perceptual saliency among the manner of sounds (i.e., nasals, stops, and fricatives), they do not discuss the effect of place articulation on the subjects' perception. Thus they do not explain why coronals are more likely to be targets in VC_1C_2V contexts than non-coronals.

2) There are some studies supporting their thesis. Although as a class nasals are highly distinct from non-nasals (Miller and Nicely, 1955), they are often confused among themselves (Householder, 1956; Malecot, 1956). Mohr and Wang (1968) found the nasals /m/, /n/, /n/ to be significantly more similar to each other than voiced [b], [d] and [g] are, which were in turn more tightly clustered than voiceless [p], [t], and [k]. Hence, when a nasal is joined to a following stop, it is not surprising that the listener has relatively less trouble hearing the nasal consonant.

However, if nasals tend to be the target of place assimilation due to weakness in place cues, then coronals should also have weak place cues, which means that [t] is the hardest sound to perceive among [p], [t], and [k]. The question is whether [t] is harder to perceive than [p] and [k]. To answer this question, an experiment was conducted in this study. Before moving on to the experiment, let us first consider those studies dealing with the perceptibility of stops.

There are 3 studies which reported the perceptibility of stops in CV context and VC context. Classic study of Miller and Nicely (1955) reported the perceptibility of consonant in CV contexts. They found that [t] proved to have the highest correct identification, followed by [p] and [k]. Householder (1956) studied the perceptibility of stops in VC contexts. Wang and Bilger (1973) examined both VC and CV contexts and [t] to have the highest correct identification, followed by [p] and [k] in both CV and VC context across all signal levels. This result is consistent with Miller and Nicely (1955).

In this section, we have examined whether coronal/non-coronal asymmetry is motivated by perceptual saliency or not. The answer seems to be negative. Hura et al. (1992) focused on the perceptual saliency of sounds with different manners of articulation without discussing the perceptual difference between the places of articulation. We will examine whether there is significant perceptual difference among the stops at different places of articulation. If a weak place cue causes coronal/non-coronal asymmetry as it does in nasals, it is predicted that coronals are predicted to be the hardest sound to perceive than non-coronals. Yet the studies on perceptibility of stops reported contradictory results. We will discuss this in detail in section 3.

2.2.2 Assimilation due to the CV cue dominance effect

Ohala (1990:265) argues that certain assimilatory sound changes (e.g., *ad+ plicare> applicare* (Italian); *primu tempus> printemps* (French), etc.) could have occurred due to less experienced listeners lacking the perceptual ability to integrate the weaker place cues in the VC transitions.

As evidence of this thesis, he reported that listeners have a tendency to misperceive a VC_1C_2V sequence as having only a single consonant at the place of articulation of C_2 in which both C_1 and C_2 were stops. He attributed this CV cue dominance effect in perception to the richer place cues in CV transition than VC transition in the VC_1C_2V contexts. As argued by Malecot (1956), place cues in VC are generally less robust than in CV transition and are even less salient in V- nasal transitions. Therefore, the CV place cues dominate and overshadow the VC transition.

There is evidence that the place of unreleased final stops, where only the formant transition cues are present are frequently misidentified (Householder, 1956), suggesting that place cues are relatively less salient in this environment. In contrast, place cues for stops in prevocalic position are generally very strong, so much so that just the burst is generally sufficient to cue place (Winitz, Scheib, and Reeds, 1972).

According to Ohala (1984; 1990) relative acoustic saliency of C_2 is responsible for the CV cue dominance effect. Thus, he reported strong CV cue dominance effect regardless of the place and manner of C_1 in VC_1C_2V contexts. This result is contradictory to Hura et al. (1992) who found no CV cue dominance effect at all even though they used the same tape splicing technique Ohala. These two contradictory studies lead us to the question of whether relative perceptual saliency is exclusively responsible for CV cue dominance. There are some studies which support that CV cue dominance effect is a function of other factors such as (a) purely auditory factors, e.g., the dominance of the most recent place cues, i.e., those from the C_2V transition (Fujimura and Streeter, 1978), and (b) closure duration (Repp, 1978).

In this section, we have examined two types of perceptual accounts: Both types of accounts are in agreement in that assimilation is motivated by the perceptual reasons. Yet, they focus on different aspects of perception: Ohala (1990) emphasizes the listeners' misperception due to strong acoustic cues of the following C_2, whereas, Hura, et al (1992) argues that the weak place cues of the sound in question induce the listeners' misperception. If Ohala's account is on the right track, there should not be coronal/non-coronal asymmetry because CV cue dominance effect does not care about the place of articulation of C_1 in the context of VC_1C_2V. On the other hand, if Hura et al. (1992) is on the right track, there also should not exist the coronal/non-coronal asymmetry because nasals and unreleased stops have weak place cues without regard to the place of articulation of the sound in question. Now we can see that neither of the two accounts provides an answer for coronal/non-coronal asymmetry. Moreover, the contradictory results with respect to CV cue dominance effect between the two accounts leave room for the further investigation. Therefore, we need to investigate (i) why CV cue dominance effect is not reported in Hura et al. (1992) and (ii) whether coronals are harder to perceive than non-coronals in coda position. Experimental results dealing with this issue will be provided in section 3.

2.3 Gestural overlap account

As we examined above, neither the articulatory nor the perceptual account provides an answer for the coronal asymmetry in place assimilation. What they predict is not consistent with what actually occurs in place assimilation.

An answer for this puzzle seems to come from Byrd (1992) and Zsiga and Byrd (1990). Using synthesized speech, Byrd (1992) showed that coronal and non-coronal asymmetry in place assimilation is due to the interaction of the two consonants in VC_1C_2V context. She found that the subjects' assimilatory errors in perception are the function of gestural overlap of two sounds. As the degree of gestural overlap of the two stops was increased by manipulating the synthesizer, more assimilatory errors were made by the subject. Contradictory to what Ohala's (1990) CV cue dominance effect would predict, Byrd (1992) found that assimilation was more readily perceived when C_1 was alveolar and C_2 was bilabial than when C_1 was bilabial and C_2 was alveolar.[3)]

Byrd provides two reasons: one is articulatory and the other is acoustic. Articulatory reason is relevant to the velocity of articulators. The velocity of tongue tip is higher than that of any other articulator and this causes the tongue tip gesture to be hidden in the gesture of other articulators. A slower movement might prove more difficult to hide (Browman and Goldstein, 1987:90). This may be the reason it is difficult for listeners to hear an alveolar stop adjacent to a velar or labial stop. Byrd's (1994) Figure 3.20 illustrates this fact by showing how the trajectory of [d] is heavily overlapped by the trajectory of [g] in natural speech. Byrd' s acoustic reason has to do with the obscuring effect of C_2. In the VC_1C_2V consonants cluster, a C_2 of different place of articulation obscures the place cues of C_1 to different degrees (Zsiga and Byrd, 1990). Since the lower lip moves slower than the tongue tip, the bilabial closure has greater effect on the formant values of the V_1 offset in the context of VCCV than the alveolar closure. When the two consonant gestures are activated simultaneously (100% overlap), the vowel offset formants correspond more closely to bilabial offset formants than alveolar offset formants (cf. Table 4 in Byrd, 1992).

The same reasoning applies to the case of velar stops. In the sequence VC_1C_2, the formant transitions of V are affected by both C_1 and C_2 as shown by Byrd (1992) and Zsiga and Byrd (1990), although C_1 is in general stronger than C_2. What Zsiga and Byrd

3) In the [db] consonant cluster, C1 is perceived more frequently as bilabial than as alveolar; in the two-word condition, 50% of subjects identified [d] as [b] at 71% of gestural overlap.

(1990) found was that the F2 and F3 transition values of the vowel preceding a coarticulated [d#g] were statistically more accurate predictor of C_2 than those of vowel preceding a [d#b] cluster both in synthesized and natural speech. Given that the formant transition of V_1 is an acoustic cue for the place identification of the unreleased C1 in the sequence of $V_1C_1C_2V_2$, C_2 affects the identification of C_1 not only by gestural overlap but also by its obscuring effect on the formant transition of V_1 in the sequence of $V_1C_1C_2V_2$. Velars seem to have stronger effect on V_1 than bilabials. Labilals have a weaker effect on the V_1 than velars, since its articulation is independent from vowel articulation, while velars share the articulator with vowels. Labial and coronal articulators are independent from vowel articulator. Thus, the acoustic cues of velars can be overlaid more on the preceding vowel than those of labials and coronals. Hence, bilabials affect C_1 only by gestrual overlap, while velars affect C_1 in two ways; gestural overlap and its effect on the formant of V_1. Coronals have weak effect on C_1 in both gestrual overlap and obscuring effect. Let us summarize this in Table 1:

Table 1. Degree of gastural overlap and obscuring effect of stops with different places of articulation

	gestural overlap	obscuring effect on V1
alveolar	weak	weak
labial	medium	medium
velar	strong	strong

This kind of reasoning may lead us to assume that velars have intrinsically stronger place cues than alveolars or labials. As mentioned before, this may be due to the fact that velars share their articulator, the tongue body, with vowels. Thus, we cannot say that a more obscuring effect means stronger place cues. The obscuring effect of velars does not indicate the strength of the place cue of velars. If velar stops have inherently stronger place cues than alveolar or bilabials, they should be perceptually salient in VC or CV context too, which is not true as illustrated in section 2.2.1.

In this section, we have examined gestrual overlap account for coronal/non-coronal asymmetry. The core of this account is that tongue tip gesture is more likely to be hidden by the articulatoy gesture of an adjacent stop and this causes misidentification by listeners. Compared with the ariculatory and perceptual accounts, gestural overlap gives better accounts for coronal/non-coronal asymmetry in place assimilation; it makes it clear how articularory aspect of a given sound (i.e., articulatory gesture) causes perceptual difference. This gestural overlap will interact with the physical characteristics of the vocal tract to determine the acoustic realization of the utterance. In this sense, gestural overlap account seems to build a bridge between articulatory and perceptual accounts.

3. The Experiment

The present experiment was designed to answer two questions: I) whether there is CV cue dominance effect across all the places of articulation of stops and ii) whether perceptual saliency account as in Hura, et al (1992) and Ohala (1990) is relevant to the coronal/non-coronal asymmetry.

An adult female native speaker of Korean recorded non-sense VCCV utterances where V was always a schwa and the single C was any of the three voiceless stops /p, k, t/ as in (4). In Korean, voiceless stops become voiced in the intervocalic position. This is why we used VCCV as a source of splicing instead of VCV.

(4) əppə
əttə
əkkə

The recording was done in a sound treated room using high quality recording equipment. The utterances were low pass filtered (8 kHz cut off frequency), digitized at a rate of 20 kHz and split into the first and second syllable waveform files as seen in (5).

(5) əp pə
ət tə
ək kə

The VCs in the second column of (5) were spliced onto the CV in the first column. The cutting was made in the middle of the closure duration of the stimuli listed in (4): the closure durations for əppə, əttə, and əkkə were 230.2 ms, 199.8 ms, and 240.4 ms respectively. VOT ranged between 16 ms and 28 ms. Splicing coincided with zero crossing in every token. Thus, (5) yielded the spliced utterances in (6).

(6) əkkə əkpə əktə

əkkə	ətkə	əpkə
əkpə	ətpə	əppə
əktə	əttə	əptə

In addition to (6), other waveform files were made, in which the duration of each consonant in VC and CV in the waveform file was reduced 50% by cutting out half of the closure duration of each C1 and C2 in (5), which were spliced, resulting in the same inventory of tokens as in (6). By doing this, the distance between the formant transition of V_1 and the burst of stop of C2 was shortened and the tokens were more similar to the utterances found in casual speech.

Tokens in which the closure duration was not shortened, had the closure duration ranges between 200 and 240 ms, while in the tokens where the closure duration was shortened, the closure duration ranges between 100 and 120 ms. Each stimulus was presented twice in the test, and 36 tokens (9x2x2) were recorded as test items in the tape used for the experiment. All tokens were randomized to create a single listening test. The tokens were presented in groups of 9 with 4 seconds inter-token intervals and 8 seconds between blocks. There was a total of 45 items in the test (36 test items, plus 9 practice items). The subjects were 15 adult native speakers of English and 5 adult native speakers of Korean, who reported no hearing problems. The stimuli were presented through earphones to the subjects. They were asked to do two tasks: to identify the intervocalic consonant C_1 by transcribing the consonant cluster(s) and to indicate whether they are sure about their responses. They marked down a vertical line next to the response when they consider their responses are more likely guesses. The second task was included in the experiment to examine subjects' reactions toward the unheard sound. The marked responses were called 'unsure responses' in the experiment. They all knew about the IPA symbols and did not need training in transcription.

4. Results

First, subjects' responses were scored in terms of error percentages, which averaged 64.5% across the entire subjects' responses. Most of the subjects' errors were assimilatory, which means that 64.5% of the subjects' responses reported C_2 instead of C_1. More detailed results are graphically shown in Figure1. In Figure 1, C_2 perception refers to the subjects' assimilatory misperception.

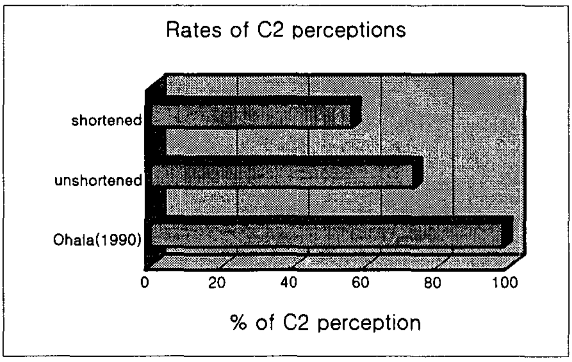

Figure 1. Rates of C2 perceptions

As shown in Figure 1, the percentage of C_2 perception report increased to 73% (for shortened stimuli) from 56% (for unshortened stimuli) as the closure duration was shortened. Also we should notice that the C_2 perception dropped from 98% to 56 %(for unshortened stimuli), compared with that in Ohala (1990). Our subjects reported less instances of misperception than those in Ohala (1990). This may be due to the fact the stop closure duration of our study is much longer than Ohala's: 200-240 ms in our study vs. 70-140 ms in Ohala's. This indicates that listeners must be considered to have a perceptual framework in which saliency is understood as linguistically significant information based on his or her knowledge of the closure duration characteristic of single, geminate, and nonhomorganic consonants (Liberman and Mattingly, 1985; Repp, 1983). Given this, we can make sense out of Hura et al's (1992). In Hura et al (1992), the stimuli were composed of two words: after the word like 'Shanim,' the second word was spliced onto it. Given that word final segments tend to be lengthened (Klatt, 1976), the duration of the final segment in the first word should be longer than that of the word-medial segment. Thus, it is natural that the closure duration of $[C_1\#C_2]$ in Hura et al. (1992) must be longer than that of word-medial consonant clusters of $[C_1C_2]$. That is a crucial difference between the previous studies. So far, we have answered the first question of whether there is CV cue dominance effect.

Now we turn to the second question: whether perceptual saliency accounts as in Hura et al. (1992) is relevant to the coronal asymmetry. In order to do this, subjects' responses were broken down by place of articulation. First, we conducted an analysis after excluding the unsure responses. Second, we conducted an analysis including the unsure responses. Let us present the result of the first analysis. It is illustrated in Figure 2.

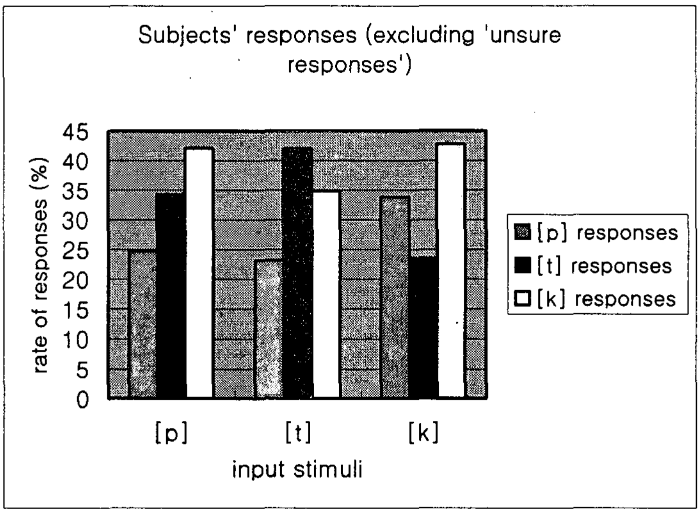

Figure 2. Subjects' responses broken down by place of articulation

At a first glance, [k] showed a slightly higher correct identification rate than [t], which is in turn showed a higher rate of correct identification than [p]. A two-way ANOVA, however, did not report a significant effect for the place of articulation: F (2, 684) =2.509 p <0.05. No significant difference was found between English and Korean subjects: F (1, 685) = 1.169, p <0.05. There was no significant interaction between the two variables of place of articulation and the speaker group either. Insignificant F ratio value for place of articulation indicates that the place of articulation of C1 did not affect subjects' correct perceptions of C1. Furthermore, the t-test between responses for stimuli [k] and ones for stimuli [t] did not show that [t] has a significantly lower rate of correct identifications compared to [k]: t-value =0.084, p <0.05. Our result does not support the claim that [t] is perceptually less robust against the obscuring effect of an adjacent consonant. Therefore, we can challenge the thesis that perceptually weak place cues of coronals cause the listeners' frequent misidentification.

When the subjects' unsure responses were included and all the responses was scored in terms of correct identification percentage in the second analysis, we had a somewhat different result, which is illustrated in Figure 3. In Figure 3, we can see that subjects' rate of correct identification were increased across all of the stimuli.

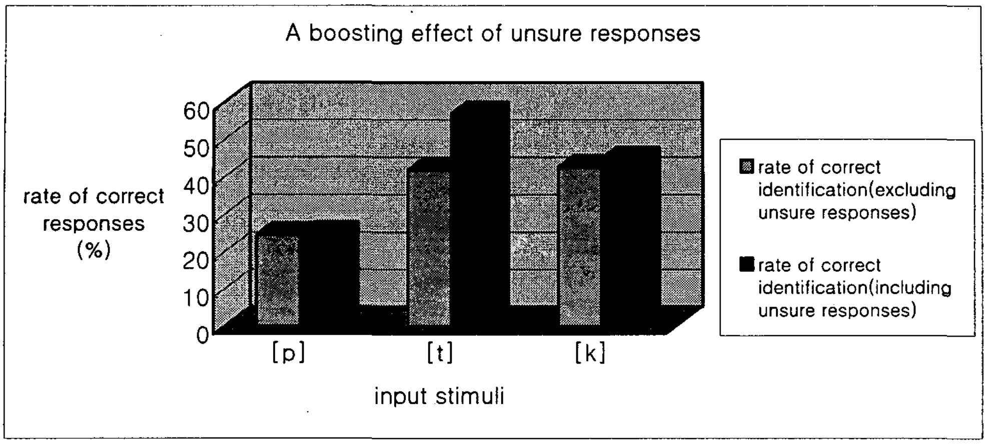

Figure 3. A boosting effect of unsure responses

The boosting effect yields [t] to show the highest correct identification rate followed by [k] and [p].[4] At this point, readers may recall that the result in the second analysis is not entirely compatible with the one shown in Figure 2. The difference between the two results lies in presence/absence of unsure responses in the analyses. When unsure responses were excluded in the statistical analysis, [t] did not show a significantly higher rate of correct responses, while they were included in the analysis, [t] turned out to have a significantly higher rate of correct responses. A closer examination of the unsure responses provided an answer for this puzzling situation. It revealed that a majority of the unsure responses were composed of [t] rather than [p] and [k]: 67% of the unsure responses corresponded to [t]. This indicates that subjects transcribed [t] when they were not sure of the place of articulation of C_1, which caused a higher rate of correct responses for [t] in the second analysis. The finding may explain why previous studies on the perception of stops reported highest correct identification rate of [t] among stops (cf. Wang and Bilger, 1973; Miller and Nicely 1955). Yet, it remains unsolved whether this implies the subjects' use of their phonological knowledge that [t] is the most unmarked consonant in their languages. Also, it may result from relatively frequent occurrence of coronals in the languages.

In the previous section, we saw that Hura et al. (1992) and Ohala (1990) have contradictory results when it comes to CV cue dominance effect. The present experiment fills the gap and explains why Hura et al. (1992) did not report any CV cue dominance

4) A closer investigation showed that 77% of the unsure responses came from the responses of English speakers.

effect, while Ohala (1990) had a very high percentage of CV cue dominance effect. My result shows that closure duration as well as acoustic saliency of onset cues plays an important role in so called 'CV cue dominance effect.' Also, no place asymmetry in perception was found in the experiment: [t] was not perceptually weaker against the CV cue dominance perception. This result indicates that the perceptual saliency account, which is based on the assumption that coronals have weaker place cues than non-coronals, cannot be an appropriate answer for the coronal/non-coronal asymmetry.

5. Discussion

The present study seeks for a phonetic explanation for coronal/non-coronal asymmetry in place assimilation. Coronal/non-coronal asymmetry refers to the typological trend that coronals are more likely targets in place assimilation than non-coronals. Many attempts to account for assimilation have been made in the field of non-linear phonology especially in the feature geometry model. Such models are descriptively adequate but they cannot answer the basic question as to what motivates typological trend.

In the previous phonetic literature, three types of accounts had been provided for the motivation of coronal/non-coronal asymmetry in place assimilation: i) Ease of articulation ii) perceptual saliency/weak place cues, and iii) the gestural overlap account. By critically reviewing those accounts, we have shown that the gestrual overlap account provides an answer for the coronal/non-coronal asymmetry. The other accounts give explanations for the motivation of other patterns of assimilation; yet they turned out to be inappropriate for the explanation for the phonological pattern in question.

Also, different results had been reported with respect to the CV cue dominance effect. The experiment conducted in this paper showed that there was CV cue dominance effect in a word-medial consonant cluster. Also, I found that no place asymmetry in perception: [t] was not weaker against the CV cue dominance effect than [p] and [k]. On the basis of this result, we can reject the idea that coronal stops might have weak place cues, which results in greater susceptibility to place assimilation than non-coronals.

The question remains whether assimilation is constrained by a single constraint or not. The answer seems to be negative. Frequent occurrence of regressive assimilation across languages appears to be motivated by CV cue dominance effect. Likewise, nasal assimilation appears to be primarily caused by perceptual constraints. On the other hand, assimilation appears to be primarily caused by perceptual constraints. On the other hand, coronal asymmetry seems to be caused by physiological rather than perceptual constraints.

The present account is based on the phonetic explanations for sound patterns claimed in such work as Ohala (1990) and Lindblom (1983). However, it does not try to put down formal accounts of phonology. Phonetic accounts can explain why some phonological patterns are pervasive across the languages, but they cannot account for the regularity, or language-specificity of those patterns.

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