Repair strategies of English biconsonantal coda clusters: An Optimality-theoretic account in conjunction with P-map

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Cho, Mi-Hui, and Shinsook Lee. 2005. Repair strategies of English biconsonantal coda clusters: An Optimality-theoretic account in conjunction with P-Map. *Studies in Phonetics, Phonology and Morphology* 11.2. 191-214. Motivated by the fact that simplification strategies in resolving English complex clusters by second (foreign) language learners differ depending on studies, this paper investigates the repair strategies employed by Korean speakers of English in the acquisition of English biconsonantal coda clusters. To this end, the paper examines the possible full range of coda cluster sequences in English. The results show that simplification strategies such as inserting a vowel or deleting a consonant are influenced by the subgrouping of the cluster sequences: obstruent only sequences, sonorant-plus-obstruent sequences, and sonorant only sequences. Based on the different results from each subgroup, the paper provides a constraint-based analysis in conjunction with P-map. Specifically, it is shown that universal markedness, P-map effects, and language transfer effects interact with one another. That is, *Complex leads to vowel epenthesis or consonant deletion and the interaction between P-map constraints and constraints from the native language transfer determines a vowel insertion site, whereas universal feature-specific faithfulness constraints decide which consonant deletes. Likewise, the alternative ranking between the P-map constraint Max(C_2) and Contiguity determines the survival of one consonant over the other in sonorant only coda sequences. (**Kyonggi University and Hoseo University)**

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1. Introduction

Korean speakers of English would modify syllable structures of English when English syllable structures do not conform to the syllable structures of their native language. In particular, consonant clusters in a syllable are not allowed in Korean whereas they are ubiquitously present in English. Given that complex consonant clusters are universally more marked than singleton consonants, complex clusters are expected to be simplified. In simplifying the syllable structures of English by Korean speakers, there would be two logical possibilities to break the clusters: insertion and deletion.

Many scholars have noticed that there are more simplification errors in the coda than in the onset (Anderson 1987, Hanchin-Bhatt and Bhatt 1997

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among others). However, simplification strategies as to insert a vowel or delete a consonant vary depending on scholars. For example, Eckman (1981) observed that Mandarin speakers of English used only vowel epenthesis when they produced word-final codas. By contrast, Anderson (1987) reported that the dominant repair strategy in coda was deletion, whereas Weinberger (1987) observed that Mandarin speakers of English showed roughly equal proportions between vowel insertion and consonant deletion in producing coda clusters. Along the same line, Hanchin-Bhatt and Bhatt (1997) noticed that different cluster-breaking strategies were employed depending on whether it is onset or coda; while insertion was dominant in onset, it was deletion that was predominant in coda.

Given the more difficulties in producing coda clusters than onset clusters, it is worthwhile to investigate the production of English biconsonantal coda clusters by Korean speakers of English in more detail. Moreover, the reason for the discrepancy among scholars with respect to cluster-breaking strategies needs to be elucidated. Thus, this paper examines the acquisition of English biconsonantal coda sequences by Korean speakers of English. The organization of the paper is as follows. Section 2 briefly reviews some previous studies on the acquisition of English syllable structures in a second (or foreign) language acquisition. Section 3 conducts an experiment on the production of English biconsonantal coda clusters by Korean learners of English. Section 4 discusses the results of the experiment. Section 5 offers a constraint-based analysis of Korean learners' repair strategies concerning English coda clusters. In addition to the ordinary OT (Prince and Smolensky 1993) constraints, the analysis employs P-map constraints developed by Steriade (2001a, b) in order to account for why some particular repair strategies are adopted while others are not. Section 6 summarizes and concludes the paper.

2. Previous studies on the acquisition of syllable structures

For the past two decades many scholars have studied on the acquisition of complex English syllable structures in a second (foreign) language acquisition. Previous studies have considered consonant clusters in a syllable, showing that marked complex clusters tend to be simplified either by vowel epenthesis or (and) consonant deletion in order to conform to native language syllable structures or at least to less marked structures. The choice of simplification strategies, however, differs depending on studies.

Anderson (1987: 287) investigated the acquisition of English syllable structures by Arabic and Chinese speakers. She elicited English target words in both onset and coda positions. The target words consisted of singletons, biconsonantal and triconsonantal sequences. Concerning the results related to biconsonantal coda clusters, she reported that the dominant simplification strategy was deletion. In particular, in the simplification of biconsonantal codas by Chinese subjects, the deletion rates took up 46% whereas the insertion rates only 2%. However, Anderson did not include the specific target items she used in the paper.

Weinberger (1987: 410) also investigated the acquisition of English word-final coda consonants including clusters by Mandarin Chinese speakers. Mandarin speakers of English showed roughly equal proportions between vowel insertion and consonant deletion in producing coda clusters. Specifically, epenthesis amounted to 9.9%, while deletion amounted to 10.2 %. The simplification strategies could reflect the biconsonantal cluster simplification process, because a very small number of triconsonantal coda sequences were included. Similar to the study of Anderson, Weinberger did not include the stimulus list in his paper.

On the other hand, according to Hachin-Bhatt and Bhatt (1997: 345), Japanese and Spanish speakers of English had more difficulties with coda clusters than with onset clusters. They reported that their subjects made only 0.1 cases of epenthesis errors in word final two-member codas whereas deletion errors increased to 4.9 cases. Thus, they claimed that epenthesis was more likely to occur in onset, while deletion was more likely to occur in coda. The coda stimuli used in their experiment were composed of sonorant-plus-obstruent and sonorant-plus-sonorant sequences, which is not the full range of possible biconsonantal sequences in English. Thus, more research involving all the possible biconsonantal clusters in English seems to be needed in order to have a more comprehensive understanding of the acquisition of English consonant sequences by second (foreign) language learners. Moreover, there have not been many experimental studies concerning the acquisition of English consonant clusters by Korean speakers. Consequently, in the following section we run an experiment to investigate the acquisition of English two member consonant clusters by Korean speakers of English.

3. Experiment

3.1 Subjects

The subjects were 60 Korean speakers of English who were freshmen at a university. The subjects were recruited from the same division and enrolled in a required English course for freshmen. All of the subjects had never had any training on English pronunciation by native speakers. Because they were drawn from the same division and they had been learning English for more than 7 years, the level of their English proficiency would be classified as intermediate.

3.2 Stimuli

As noted in the review section of previous studies, there has been no study that investigates the full range of coda clusters in English, even though we expect that cluster-breaking strategies might vary depending on the target stimuli. Specifically, the partial inclusion of all possible biconsonantal clusters or the difference in the stimuli list employed in different experiments might influence the cluster-breaking choice between insertion and deletion. In other words, clusters may behave differently based on the component consonants. Consequently, instead of lumping all cluster types together, we examine the clusters based on the sonority of the component consonants. Let us first consider the possible full range of coda cluster sequences in English. According to Giegerich (1992: 132), the pulses of the air stream in speech are manifested as peaks in sonority, and thus the sonority of a sound can be defined as relative loudness compared to other sounds. As a result, speech sounds are ranked based on their relative sonority where voiceless stops are least sonorous while vowels are most sonorous (Selkirk 1984, Clements 1990).

(1) Sonority scale

High	Vowels
	Glides
	Liquids
	Nasals
Low	Obstruents

It is well-known that complex onsets and codas tend to be arranged based on the sonority hierarchy in spite of few exceptions (Kenstowicz 1994: 254). The construction of complex onsets and codas is constrained as being guided by Sonority Sequencing Principle (Selkirk 1982). Specifically, consonant sequences in a syllable are arranged in such a way that sonority values fall from the peak to the margins of the syllable. Thus, word-final biconsonantal clusters in English can be grouped together into several large classes based on sonority, as given in the following table.[1]

[1] When the first consonant C_1 is voiced as in the sonorant-plus-obstruent sequences, the following C_2 can be either voiceless or voiced. However, we include only voiceless C_2 for simplicity and consistency of the stimulus list. If a stimulus is composed of obstruent-plus-obstruent sequences, only voiceless sequences are possible in a morpheme.

Table 1. Coda Stimulus classification by sonority

Obs+Obs	Fricative+Stop (*lift, soft, grasp wasp, last, ghost, task, dusk*)	
	Stop+/s/ (*collapse, lapse, fax, box*)	
	Stop+/t/ (*adopt, abrupt, product, act*)	
Son+Obs	Nasal	Nasal+Stop (*lamp, lump, account, hint, trunk. think*)
		Nasal+Affricate (*lunch, ranch*)
		Nasal+Fricative (*triumph, nymph, month, seventh, offense, importance, strength, length*)
	/l/	/l/+Stop (*help, gulp, guilt, bolt, bulk, silk*)
		/l/+Affricate (*Welch, belch*)
		/l/+Fricative (*wolf, yourself, else, false, health, wealth*)
	/r/	/r/+Stop (*harp, sharp, art, effort, bark, clerk*)
		/r/+Affricate (*march, research*)
		/r/+Fricative (*scarf, barf, north, worth, curse, course, harsh, marsh*)
Son+Son	/l/+/m/ (*film, Stockholm*)	
	/r/+/l/ (*girl, snarl*)	
	/r/+Nasal (*charm, uniform, pattern, popcorn*)	

In the table, coda clusters are divided into three large classes with falling sonority (or equal sonority): obstruent-plus-obstruent, sonorant-plus-obstruent, and sonorant-plus-sonorant sequences. Therefore, we designed the stimuli list of the present experiment based on the subgroupings in the above table and assigned two words per each small subgroup, which are provided in parentheses.

3.3 Procedure

For the production test, each subject was asked to read the given sentence list clearly with a pause between sentences. Each sentence contains one coda cluster stimulus at the end of the sentence so that sentence-final clusters may not be affected by any adjacent elements. The subjects' readings were tape-recorded using a high-quality MD recorder and transcribed only for the target sounds under investigation by four people who had training on phonetic transcription; one of them was a native speaker of American English. The inter-rater reliability was about 90%.

4. Results

4.1 Overall results

In coda clusters of two-members, insertion errors and deletion errors occurred in roughly equal proportions, 12% insertion and 10% deletion, but the insertion rates were still a little bit higher than the deletion rates.

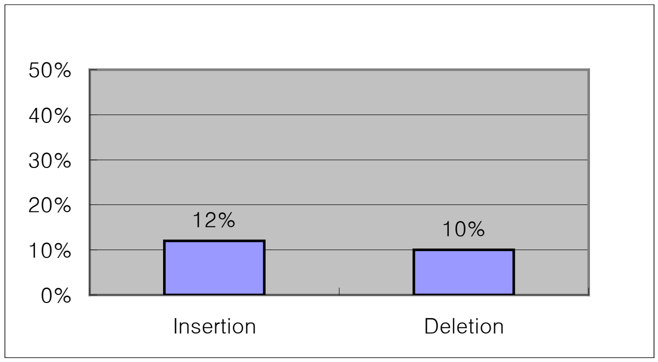

Figure 1. Insertion and deletion rates in biconsonantal coda cluster simplification

Let us compare the results with those in Hachin-Bhatt and Bhatt (1997). As mentioned in the previous section, Hachin-Bhatt and Bhatt investigated the acquisition of English syllable structure by Japanese and Spanish speakers. Japanese and Spanish speakers of English had more difficulties with coda cluster sequences than with onset cluster sequences. In particular, the roughly equal occurrence of insertion and deletion rates in biconsonantal coda clusters in Figure 1 is not congruous to the result obtained by Hanchin-Bhatt and Bhatt (1997: 345), where their subjects made only 0.1 cases of epenthesis errors in word final two-member codas whereas their deletion errors increased to 4.9 cases. Hanchin-Bhatt and Bhatt's main claim is that epenthesis was more likely to occur in onset, while deletion was more likely to occur in coda. By contrast, in our result deletion and insertion rates did not show much difference in coda. Then, why did this divergence occur concerning the cluster-breaking strategies in coda cluster sequences?

In the study of Hanchin-Bhatt and Bhatt, the stimuli were 72 monosyllabic pesudo-English words. The 72 monosyllabic stimuli in Hanchin-Bhatt and Bhatt are classified as follows.

Table 2. Stimuli in Hanchin-Bhatt and Bhatt (1997: 338)

Initial CC- 12x3=36	Stop+glide (12)
	Stop+liquid (12)
	Fricative+liquid (12)
Final –CC 12x3=36	Liquid+stop (12)
	Liquid+fricative (12)
	Liquid+nasal (12)

Importantly, the stimuli for coda clusters were all composed of only liquid-plus-obstruent coda sequences and liquid-plus-nasal sequences. In our experiment, however, the stimuli consisted of the full range of coda cluster sequences in English, as shown in the corpus of Table 1: obstruent-plus-obstruent, sonorant-plus-obstruent, and sonorant-plus-sonorant sequences. Then, the partial inclusion of coda clusters in Hanchin-Bhatt and Bhatt might make the difference between the two experiments.

4.2 Syllabification in coda cluster sequences

Although the target-appropriate syllable structure was predominant, coda cluster syllabification showed complex patterns of cluster simplification. The dominant errors in coda clusters were to modify the final, rightmost element.

(2) Coda cluster simplification pattern

$-C_1C_2$ (70x60=4200)	a. $-C_1.C_2$**V**	9% (355)
	b. $-C_1$	5% (216)
	c. $-C_2$	5% (200)
	d. $-C_1$**V**C_2	3% (116)

The modification of the rightmost element occurred either by inserting a vowel (2a) or deleting the final consonant (2b). Vowel insertion after the rightmost, final consonant is most predominant, taking up 9% for biconsonantal clusters. Deletion of the final consonant occurred about the same proportion as the deletion of the penultimate consonant, amounting to 5% for each. In biconsonantal clusters final vowel insertion occurred when the final consonant was an obstruent (e.g., [ækt**ɨ**] *act*). By contrast, final vowel insertion rarely occurred in sonorant-plus-sonorant sequences (e.g., [fɪl**ɨ**m] *film*). Instead, a vowel tended to be inserted between the sonorant consonants (2d). Since the vowel insertion patterns depended on sonority of adjacent consonants, the results are further analyzed based on the sonority scale of the coda stimuli in the next section. Furthermore, we provide a constraint-based analysis of the syllable structures that emerged based on the subgrouping.

5. A Constraint-based Analysis of Korean-English interlanguage syllabification

The modified syllable structures in Korean-English interlangauge are analyzed within the framework of Optimality Theory (Prince and MaCarthy 1993; McCarthy and Prince 1995) in conjunction with the perceptual mapping (henceforth, P-map) theory developed by Steriade (2001a, b). The aim of perceptual phonology is to account for productive phonology through perceptual factors. The component of the p-map is linked to the grammar in such a way that rankings among correspondence constraints are indexed to the perceived similarity of the input-output differences they refer to. For example, if the *s*/zero contrast is a more distinctive one than the *t*/zero contrast in a certain environment, then Max(s) outranks Max(t) with reference to that environment and also Dep(s) would outrank Dep(t). Consequently, the segment /s/ is less likely to be the target of deletion or insertion than the segment /t/ in a specific environment. In the next subsection we analyze the cluster simplification strategy for the obstruent-plus-obstruent sequences.

5.1 Obstruent-plus-obstruent sequences

5.1.1 General patterns and insertion

In obstruent-plus-obstruent sequences deletion and insertion rates did not show much difference, with 13% and 10%, respectively. The most dominant change was to insert a vowel after the final consonant (11%). The consonant deletion rates also took place in roughly equal proportions (10%). However, the choice of which consonant deleted showed variation between C_1 and C_2. The deletion of the final consonant C_2 took up 6% whereas the deletion of the penultimate consonant C_1 4%. Also, there were a very few cases of vowel insertion between C_1 and C_2 (2%). Notice that the insertion of two vowels before and after the final consonant (–C_1V.C_2V) took place only 6 cases. Since the emerged syllable structure form took up less than 1%, it was not listed.[2]

(3) Coda cluster simplification in obstruent-plus-obstruent sequences

-C_1C_2 (16x60=960)	a. -C_1.C_2**V**	11% (109)
	b. -C_1	6% (62)
	c. -C_2	4% (40)
	d. -C_1**V**C_2	2% (19)

The motivation for the cluster-breaking strategy is well expressed by the undominated constraint *Complex which prohibits a cluster in a syllable. The choice between vowel insertion and consonant deletion varies depending on an individual subject. Some subjects tend to adopt the insertion strategy consistently whereas some other subjects adopt the deletion strategy consistently. The variation as to vowel insertion or consonant deletion can be attributed to the alternative rankings between Max(segment) and Dep(segment). When Max(segment) outranks Dep (segment), vowel insertion occurs.

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2 Nonetheless, the rare syllable structure –C_1V.C_2V in Korean-English interlanguage is the optimal form in Korean loanword phonology.

(4) Vowel insertion ranking
*Complex>>Max(segment)>>Dep(segment)

The insertion site varies, although final vowel insertion prevails. The absolute prevalence of final insertion (3a) over vowel insertion between two consonants (3d) may be due to perceptibility effects. That is, a vowel is inserted after the final consonant C_2, instead of the first stop C_1 so that the perceptual similarity of the target sound from the source language is maximized in the recipient language. According to many scholars such as Henderson and Repp (1982) and Browman and Goldstein (1990), a sequence of two stops C_1C_2 in English is produced with a gestural overlap where there is no audible release for the first stop C_1. Then, vowel insertion after the first stop C_1 would be very distinctive to the stop-release pattern in English. By contrast, vowel insertion after the final stop C_2 would be a better approximation to the stop-release pattern in English. As claimed by many scholars such as Jun (2002) and Kang (2003) concerning English loanword adaptation in Korean, there is correlation between stop release and vowel insertion in such a way that Korean stop-plus-inserted vowel [ɨ] sequences and the corresponding English release stop are acoustically very similar. This is not uncommon given the observation by Parker (1977) in which a released voiced stop in English is an acoustic syllable consisting of a stop plus a vocalic sound. Then, it may be generalized to release-to-vowel insertion that makes vowel insertion possible mainly after a released consonant, as in Kang (2003: 235).

In Steriade's term the most confusable (i.e., perceptually similar) input-output pair is chosen for the maximization of the perceptual similarity based on the relative confusability between the input and the modified output. That is, vowel insertion after the final consonant C_2 would be more confusable with the English input than vowel insertion after the first vowel C_1 because the lesser perceptibility of the first consonant C_1 suppresses the possibility of vowel insertion after C_1. If vowel insertion did occur after the first consonant C_1, then an unreleased consonant would become released and that would be too distinct from the target. The less perceptibility of the first consonant C_1 is also applied even in the sequence of fricative-plus-stop. The insertion of a vowel after the less perceptible consonant (C_1) is more distinctive than the vowel insertion after the more perceptible consonant (C_2). Therefore, the syllable structure -C_1C_2**V** is judged to be more similar to the target -C_1C_2 than the syllable structure -C_1**V**C_2.

The fact that the insertion of a vowel at the end is less distinct than inserting a vowel between consonants can be formulated as following context-dependent P-map constraints and constraint ranking.

(5) Similarity ranking between two contrasts: vowel insertion after C_1 and after C_2 in the sequence of -C_1C_2.

a. Dep(V)/C_1___ : There is no zero/vowel contrast in context of C_1___ between input and output such that the input contains zero after C_1 and the output contains a vowel in the same environment, after C_1.

b. Dep(V)/C_2___ : There is no zero/vowel contrast in context of C_2___ between input and output such that the input contains zero after C_2 and the output contains a vowel in the same environment, after C_2.

c. Ranking: Dep(V)/C_1___>> Dep(V)/C_2___

Korean-English interlanguage does not reflect either English phonology or Korean phonology because final vowel insertion is neither motivated in English nor in Korean. Rather, the ranking reflects the evaluation of the distinct degrees of auditory salience concerning the zero/vowel contrast in a specific environment by Korean speakers of English.

With these constraints and constraint ranking let us consider the following tableau.

(6) Final vowel insertion in the sequence of -C_1C_2 (e.g., wasp [waspɨ])

-C_1C_2	*Complex	Max (segment)	Dep(V)/ C_1___	Dep(V)/ C_2___
☞ a. -C_1.C_2**V**				*
b. -C_1		*!		
c. -C_2		*!		
d. -C_1**V**C_2			*!	
e. -C_1**V**.C_2**V**			*!	*
f. -C_1C_2	*!			

Candidates (b) and (c) with consonant deletion are eliminated by the Max(segment) constraint that prohibits segmental deletion. Candidates (d) and (e) are ruled out because of the vowel insertion after the first consonant C_1, which causes more distinctive contrast compared to the vowel insertion after the final consonant C_2. Candidate (f) fatally violates the constraint *Complex that prohibits consonant clusters in a syllable, thus ruling it out of consideration. Therefore, candidate (a) with final vowel insertion becomes the winner given that it only violates the constraint Dep(V)/C_2___ which penalizes less distinctive vowel insertion at the end.

Next the occurrence of the syllable structure -C_1**V**C_2 needs to be accounted for, although the frequency is very low (2%). The vowel insertion between two consonants is unexpected, given the P-map effect whereby final vowel insertion is less distinctive than internal vowel insertion. The sequences of obstruent-plus-obstruent consists of three small subgroups: (i) a fricative is followed by a stop; (ii) a stop is followed by /s/;

(iii) a stop is followed by /t/. Importantly, the distribution of the syllable structure -C_1**V**C_2 with internal vowel insertion was biased such that it mostly occurred in the words *lift*, *soft*, *grasp*, and *wasp* in the subgroup (i), a fricative with a following stop. When the first consonant C_1 is a stop as in the subgroups (ii) and (iii), vowel insertion after a stop occurred only 3 cases for the stimulus *collapse*. Thus, the occurrence of vowel insertion after a stop is too accidental to be treated as a pattern. The occurrence of vowel insertion after a fricative can be accounted for by a transfer effect from the native language. In Korean coda consonants are always unreleased due to coda neutralization at the surface level. Thus, coda inventory includes unreleased stops [p, t, k] and sonorants [m, n, ŋ, l]. A released consonant is always interpreted as an onset. Consequently, no fricatives can occur in the coda position in Korean because these are inherently released. Because of this Korean-specific coda neutralization effect, a vowel may be inserted after English fricatives in Korean-English interlanguage.

(7) Coda neutralization effect
Fricative/Onset: Fricatives are onsets.

When vowel insertion after a less perceptible C_1 occurs, the constraint Fricative/Onset outranks the P-map constraints.

(8) Internal vowel insertion in the sequence of -C_1C_2 (e.g., wasp [wasɨp])

-C_1C_2	*Complex	MAX (segment)	Fric/ Onset	Dep(V) /C_1___	Dep(V)/ C_2___
a. -C_1.C_2**V**			*!		*
b. -C_1		*!	*		
c. -C_2		*!			
☞d. -C_1**V**C_2				*	
e. –C_1**V**.C_2**V**				*	*!
f. -C_1C_2	*!		*		

Candidate (c) is out due to the fatal violation of the constraint Max(segment). Candidate (b) is similarly eliminated because of its fatal violation of Max(segment). In addition, it violates the constraint of Fricative/Onset because the first consonant C_1 that is a fricative is not realized as an onset but as a coda. Likewise, candidate (a) that is the winner in the tableau (6) is out of consideration because the Fricative/Onset constraint is high ranked. Candidate (f) incurs a fatal violation of the constraint *Complex. The choice then is between the two candidates (e) and (d). While candidate (e) with two vowel insertion violates both of Dep constraints, candidate (d) only violates one Dep constraint. Therefore, candidate (d) surfaces as the optimal output.

The transfer effect does not always occur whenever English fricatives are located as the first consonant in the sequence of -C_1C_2. Some subjects may still rank the P-map constraints over the constraint of Fricative/Onset so that not every English fricative is interpreted as an onset. Ranking variation as to whether the P-map effect prevails or the transfer effect prevails in the insertion strategy is summarized in (9).

(9) Insertion ranking variation due to the interaction between the P-map effect and the transfer effect
  a. The dominance of the P-map effect over the transfer effect
     *Complex>>Max(segment)>> Dep(V)/C_1___>> Dep(V)/C_2___, Fric/Onset
  b. The dominance of the transfer effect over the P-map effect
     *Complex>>Max(segment), Fric/Onset >> Dep(V)/C_1___>> Dep(V)/C_2___

5.1.2 Deletion

In the consonant deletion strategy the faithfulness constraint Dep outranks the Max constraint. In a similar vein to vowel insertion, it would not be the second consonant C_2 but the first consonant C_1 that is deleted in a sequence of two consecutive consonants -C_1C_2 given that the lesser perceptibility of the first consonant C_1 leads to its loss.

(10) Similarity ranking between two contrasts: C_1 deletion and C_2 deletion in the sequence of -C_1C_2: Dep[3]>>Max(C_2)/C_1__>>Max(C_1)/__C_2

This expectation, however, is not always born out. Interestingly, the deletion rates of the first consonant C_1 (3c) and those of the second consonant C_2 (3b) were roughly about the same, 4% and 6%, respectively. Thus, it turned out that the less perceptible consonant C_1 due to the gestural overlap did not always delete. The more perceptible consonant C_2 sometimes deleted.

Then, let us consider the stimuli in more detail in order to examine the case in which the more perceptible C_2 deletes. In the subgroup (i) where a fricative is followed by a stop, the following stop can be categorized depending on the place of articulation. When the stop is coronal as in *lift*, *soft*, *last*, and *ghost*, it was the fricative that survived in most cases. By contrast, when the stop is labial and velar as in *grasp*, *wasp*, *task*, and *dusk*, it was either the stop or the fricative that survived. In other words, the survival ratio of the stops was too high to be treated as an exception in the case of labial and velar stops. The survival of either peripheral stops or fricatives was confirmed by the data in the small subgroup (ii) where a stop is followed by /s/. In the subgroup (ii), the final consonant /s/ was expected

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[3] Although we use the constraint Dep, it is actually a simplified version of P-map constraints Dep(V)/C_1___ and Dep(V)/C_2. The same holds true for the Max constraint, which will be discussed below.

to survive given the perceptibility effect. Nevertheless, the stops that are labial or velar as in *collapse, lapse*, *fax*, and *box* sometimes survived. In other words, the deleted consonant was either the stop or the fricative /s/. The survival of the peripheral stops in a less perceptible context was also observed in the subgroup (iii) in which a stop is followed by /t/. Although the peripheral stops were in a less perceptible position as in *abrupt*, *adopt*, *act*, and *product*, the survival ratio of the stops was twice as much as the final consonant /t/.

The survival of fricatives over coronal stops is well observed in standard OT by ranking Max(+continuant) higher than Max(-continuant) as in (11a). This is not uncommon given the marked nature of the inherent noisiness of fricatives. Likewise, the survival of peripheral stops over the coronal stop /t/ is interpreted as the dominance of Max(peripheral) over Max(coronal) as in (11b). The dominance of Max(peripheral) is understandable given the fact that the articulatory gesture of coronal consonants is very rapid; consequently, its formant structure is brief compared to that of peripheral consonants (Jun 1995). The variation as to delete a peripheral stop or a fricative is due to the alternative rankings between the constraints Max(+continuant) and Max(peripheral). When Max(+continuant) overrides Max(peripheral) as in (11c), a fricative survives regardless of whether it is C_1 or C_2. Similarly, when Max(peripheral) outranks Max(+continuant) as in (11d), a peripheral stop survives regardless of its position.

(11) Deletion ranking variation

a. Fricatives survive over stops: Dep>>Max(+cont)>>Max(-cont)
b. Peripheral stops survive over coronal stops:
Dep>>Max(peri)>>Max(cor)
c. Fricatives survive over peripheral stops:
Dep>>Max(+cont)>>Max(peri)
d. Peripheral stops survive over fricatives:
Dep>>Max(peri)>>Max(+cont)

The context-free dominance of Max(+continuant) and Max(peripheral) is at odds from the perspective of perceptual phonology. From a perceptual point of view different outcomes would result from different positions. Since the perceptibility effect does not affect the predominance of Max(+continuant) and Max(peripheral), the P-map constraints in (10) are low ranked in such a way that Max(C_2) is in tie with the lowest conventional OT constraints above.

With these constraint rankings let us consider the case where the coronal stop /t/ rarely survives when the coda cluster sequences are composed of fricative and stop.

(12) Coronal stop deletion in the sequence of fricative-plus-coronal stop (e.g., last [las])

-C_1C_2	*Complex	Dep	Max (+cont)	Max (-cont)	Fric/ Ons	Max (C_2)	Max (C_1)
a. -$C_1.C_2$**V**		*!			*		
☞b. -C_1				*	*	*	
c. -C_2			*!				*
d. -C_1**V**C_2		*!					
e. -C_1**V**.C_2**V**		*!*					
f. -C_1C_2	*!				*		

In (12) candidates (a), (d), and (e) are all eliminated due to the fatal violations of the Dep constraint. Candidate (f) fatally violates the *Complex constraint, and accordingly, it is out. Thus, the decision passes down to candidates (b) and (c). While candidate (b) violates lower ranked Max(-continuant), candidate (c) violates higher ranked Max(+continuant). Therefore, candidate (b) becomes the winner.

Next case is variation as to whether the peripheral stop /p/ deletes or the fricative /s/ deletes. The first tableau (13) accounts for the survival of the fricative /s/ by deleting the peripheral stop /p/. The second tableau (14) illustrates the opposite case that the peripheral stop /p/ survives over the fricative /s/.

(13) Peripheral stop deletion in the sequence of peripheral stop-plus-fricative (e.g., collapse [kəlæs])

-C_1C_2	*Complex	Dep	Max (+cont)	Max (peri)	Fric/ Ons	Max (C_2)	Max (C_1)
a. -$C_1.C_2$**V**		*!					
b. -C_1			*!			*	
☞c. -C_2				*	*		*
d. -C_1**V**C_2		*!			*		
e. –C_1**V**.C_2**V**		*!*					
f. -C_1C_2	*!				*		

(14) Fricative deletion in the sequence of peripheral stop-plus-fricative (e.g., collapse [kəlæp])

-C_1C_2	*Complex	Dep	Max (peri)	Max (+cont)	Fric/ Onset	Max (C_2)	Max (C_1)
a. -$C_1.C_2$**V**		*!					
☞b. -C_1				*		*	
c. -C_2			*!		*		*
d. -C_1**V**C_2		*!			*		
e. –C_1**V**.C_2**V**		*!*					
f. -C_1C_2	*!				*		

When Max(+continuant) outranks Max(peripheral) as in the tableau (13), the peripheral stop /p/ deletes. Thus, candidate (c) is selected optimal in the tableau (13). By contrast, in the tableau (14) candidate (b) is the winner when Max(peripheral) is higher ranked than Max(+continuant).

Variation between the coronal stop deletion and peripheral stop deletion also occurs, although the deletion of the coronal stop is dominant. Let us first consider the common case of coronal stop deletion.

(15) Coronal stop deletion in the sequence of peripheral stop-plus-coronal stop (e.g., product [prədʌk])

$-C_1C_2$	*Com plex	Dep	Max (peri)	Max (cor)	Fric/ Ons	Max (C_2)	Max (C_1)
a. $-C_1.C_2$**V**		*!					
☞b. $-C_1$				*		*	
c. $-C_2$			*!				*
d. $-C_1$**V**C_2		*!					
e. –C_1**V**.C_2**V**		*!*					
f. $-C_1C_2$	*!						

Since the constraint Max(peripheral) outranks the constraint Max(coronal), the candidate (b) is selected over the candidate (c).

The standard correspondence constraints are able to predict the preference for the fricatives and peripheral stops as the surviving consonant based on markedness regardless of position. Yet, we still need the P-map constraints in (10) relative to position in accounting for the survival of the word-final /t/, which is expected to delete because of its unmarked nature. Since /t/ is located in the perceptually salient position C_2 in the sequences of $–C_1C_2$, it survives; consequently, the P-map constraint Max(C_2)/C_1__ outranks the conventional correspondence Max(peripheral), as the following tableau shows.

(16) Peripheral stop deletion in the sequence of peripheral stop-plus-coronal stop (e.g., product [prədʌt])

$-C_1C_2$	*Com plex	Dep	Max (C_2)	Max (peri)	Max (cor)	Fric/ Ons	Max (C_1)
a. $-C_1.C_2$**V**		*!					
b. $-C_1$			*!		*		
☞c. $-C_2$				*			*
d. $-C_1$**V**C_2		*!					
e. –C_1**V**.C_2**V**		*!*					
f. $-C_1C_2$	*!						

Candidate (b) which is the winner in the tableau (15) is not selected as the optimal output this time because it incurs a fatal violation of the P-map constraint $Max(C_2)/C_1\_\_$. Thus, candidate (c) which best satisfies the constraint rankings becomes optimal.

In summary, the crucial constraint rankings for the consonant deletion variation in Korean-English interlanguage with respect to obstruent only sequences are provided below.

(17) Consonant deletion ranking variation

*Complex>>Dep>>Max(+cont)>>Max(-cont), Fric/Onset, Max(C_2)>>Max(C_1)
Max(+cont)>>Max(peri)
Max(peri)>>Max(+cont)
Max(peri)>> Max(cor)
Max(C_2)>>Max(peri)>>Max(cor), Fric/Onset>>Max(C_1)

The dominance of Max(+continuant) and Max(peripheral) regardless of positions can be understood as being supportive of the traditional markedness view because it has nothing to do with the perceptibility effect which is relative to position. Nevertheless, certain candidates like candidate (b) in the tableau (16) are ruled out by perceptual factors depending on position. Thus, it is shown that the target of deletion cannot be determined by either markedness conditions alone or perceptibility effects alone. Instead, it is viewed that conventional correspondence constraints based on markedness and the P-map constraints based on perceptual factors are interwoven in the constraint rankings to account for the variation patterns of consonant deletion.

5.2 Sonorant-plus-obstruent sequences

Sonorant-plus-obstruent sequences are composed of the following small subgroups: (i) nasal+stop, (ii) nasal+affricate, (iii) nasal+fricative, (iv) /l/+stop, (v) /l/+affricate, (vi) /l/+fricative, (vii) /r/+stop, (viii) /r/+affricate, and (ix) /r/+fricative. The syllable structures that emerged in sonorant-plus-obstruent sequences were not quite different from those in obstruent-plus-obstruent sequences (3). The only syllable type that occurred less than 1% compared to (3) was the syllable structure with internal vowel insertion. The rare occurrence of internal vowel insertion in the sequence of sonorant-plus-obstruent is understandable given the fact that sonorant consonants before an obstruent are never realized with release of air (Kang 2003: 238). Since sonorants are not released, a vowel cannot be inserted after the sonorants confirming the release-to vowel insertion hypothesis in Kang. Hence, vowel insertion after the pre-final sonorant consonants cannot occur because that would be perceptually too distinct from the target English. By contrast, obstruent consonants such as stops and fricatives can be released, and thus vowel insertion after the final stop or fricative makes better approximation to the obstruent release pattern of English.

(18) Coda cluster simplification in sonorant-plus-obstruent sequences

$-C_1C_2$ (46x60=2760)	a. $-C_1.C_2$**V**	9% (243)
	b. $-C_1$	4% (107)
	c. $-C_2$	3% (75)

In sonorant-plus-obstruent sequences the most predominant syllable structure that occurred was with final vowel insertion (9%). Consonant deletion rates amounted to 7%. The choice as to which consonant deleted varied; sonorant consonant deletion rates took up 4% whereas obstruent consonant deletion rates took up 3%.

The dominance of final vowel insertion over internal vowel insertion is accounted for in the same way that handles final vowel insertion of obstruent-plus-obstruent sequences in (6). That is, a final vowel is epenthesized at the end of a word because it is the least distinct way to insert a vowel between the two consonants. This is expressed by adopting P-map-based Dep constraints (Dep(V)/C_1___>> Dep(V)/C_2___). Final vowel insertion is especially dominant when the final consonant is articulated in the place of palatal. If a word ends with the palatal affricate [tʃ] or fricative [ʃ] as in *lunch*, and *harsh*, the front vowel [i] is inserted instead of the central [ɨ] due to palatalization that shares palatal place of articulation between the palatal consonants and the front vowel [i].

Differently from insertion patterns, the deletion rates of sonorant-plus-obstruent sequences vary. Sometimes obstruent consonants delete (4%), but some other times sonorant consonants delete (3%). The deletion of obstruent consonants is understood as the universal tendency where sonorant consonants are preferred as a coda consonant. Thus, in many languages non-sonorants may not appear in the codas (e.g., Ponapean, Mandarin Chinese, Hausa) whereas there are no languages in which some obstruents but no sonorant consonants appear in the codas. Obstruents in syllable codas are thus typologically marked compared to coda sonorants (Clements 1990, Goldsmith 1990). This tendency is formulated as the following constraint.

(19) Coda Sonority: A more sonorous consonant is required in coda position.

Because of the constraint Coda Sonority, sonorous C_1 despite of being in a less perceptible context did not delete but obstruent C_2 in a more perceptible position deleted in the two consonant sequences $-C_1C_2$. Therefore, Coda Sonority outranks the P-map constraint Max(C_2)/C_1__.

However, it was not always the case where only less sonorous consonants deleted. There were also cases in which more sonorous consonants deleted, too. The deletion of more sonorous consonants is accounted for by ranking the P-map constraint over the Coda Sonority constraint so that the consonant in a less perceptible position can be deleted. Among the sonorous consonants, nasals and liquids, it was the most sonorous /r/ that deleted most frequently. This is expected given the fact that the most sonorous /r/ is most similar to the preceding vowel, thus being most confusable with null (Steriade 2001b). Along the same line, Kang (2003: 229) also notices that vowel-plus-coda [r] sequences are acoustically more like a diphthong than a vowel-plus-coda consonant. In order to maintain perceptual similarity between the source and target language, the most similar one to adjacent segments is deleted, in this case postvocalic /r/, if deletion is necessary. In this way, perceptual similarity can be maximized. The following summarizes constraint rankings for sonorant-plus-obstruent sequences.

(20) Constraint rankings for sonorant-plus-obstruent sequences
- a. Final vowel insertion
  - *Complex>>Max(segment)>> Dep(V)/C_1___>> Dep(V)/C_2___
- b. Deletion
  - (i) Obstruent deletion
    - *Complex>>Dep>>Coda sonority>>Max(C_2)/C_1__>>Max(C_1)
  - (ii) Sonorant deletion
    - *Complex>>Dep>> Max(C_2)/C_1__>> Coda sonority , Max(C_1)

With these rankings let us first consider the case of final vowel insertion.

(21) Final vowel insertion in sonorant-plus-obstruent sequences (e.g., guilt [gɪltɨ])

-C_1C_2	*Complex	Max (seg)	Dep(V)/C_1 ___	Dep(V)/C_2 ___
☞ a. -C_1.C_2**V**				*
b. -C_1		*!		
c. -C_2		*!		
d. -C_1**V**C_2			*!	
e. -C_1**V**.C_2**V**			*!	*
f. -C_1.C_2	*!			

Candidates (b) and (c) with consonant deletion are ruled out because they fatally violate the Max constraint. Candidate (f) is eliminated due to the constraint *Complex. Among candidates (a), (d), and (e), candidates (d) and (e) insert a vowel in a more perceptible position, thus incurring fatal violations of Dep(V)/C_1___. Therefore, candidate (a) with final vowel insertion becomes the winner because it inserts a vowel in a perceptibly less distinctive position.

Next case is consonant deletion. The tableaux in (22) and (23) show variation of consonant deletion between sonorous consonants and obstruent consonants. In specific, the tableau in (22) illustrates that high-ranked universal markedness constraints on coda consonants choose the optimal output, while the tableau in (23) indicates that high-ranked P-map constraints based on perceptual factors choose the optimal output.

(22) Obstruent deletion in sonorant-plus-obstruent sequences (e.g., guilt [gɪl])

$-C_1C_2$	*Complex	Dep	Coda Son	Max (C_2)	Max (C_1)
a. $-C_1.C_2\mathbf{V}$		*!			
☞b. $-C_1$				*	
c. $-C_2$			*!		*
d. $-C_1\mathbf{V}C_2$		*!			
e. $-C_1\mathbf{V}.C_2\mathbf{V}$		*!*			
f. $-C_1C_2$	*!				

(23) Sonorant deletion in sonorant-plus-obstruent sequences (e.g., guilt [gɪt])

$-C_1C_2$	*Complex	Dep	Max (C_2)	Coda Son	Max (C_1)
a. $-C_1.C_2\mathbf{V}$		*!			
b. $-C_1$			*!		
☞c. $-C_2$				*	*
d. $-C_1\mathbf{V}C_2$		*!			
e. $–C_1\mathbf{V}.C_2\mathbf{V}$		*!*			
f. $-C_1C_2$	*!				

In both tableaux candidates (a), (d), and (e) are out due to the fatal violations of the Dep constraint. Candidate (f) fatally violates the markedness constraint *Complex, thus being out of consideration. Then, the competition passes down to candidates (b) and (c). In the tableau (22) candidate (c) with an obstruent coda incurs a fatal violation of the constraint Coda Sonority, and accordingly, is eliminated. Therefore, candidate (b) with a sonorant coda becomes the winner. By contrast, in the tableau (23) candidate (b) violates the high-ranked P-map constraint and cannot be the winner. Instead, candidate (c) with an obstruent coda becomes the winner since the surviving obstruent coda is in a more perceptible position.

5.3 Sonorant-plus-sonorant sequences

In sonorant-plus-sonorant sequences a little bit of a different syllable structure pattern other than those in obstruent-plus-obstruent and sonorant-plus-obstruent sequences emerged. First, there were more syllable structure errors than other cluster sequences; vowel insertion took up 15% whereas consonant deletion 28%. Second, there were more deletion errors than insertion errors.

(24) Coda cluster simplification in sonorant-plus-sonorant sequences

$-C_1C_2$ (8x60=480)	a. $-C_2$	18% (85)
	b. $-C_1\mathbf{V}C_2$	15% (74)
	c. $-C_1$	10% (47)

When vowel insertion occurred, a vowel was inserted only between consonants, not after the final consonant. Internal vowel insertion as well as final vowel insertion is uncommon in sonorant-plus-sonorant sequences because sonorant consonants are realized without obstruction of air in the mouth, thus without apparent release of air. This is especially evident in loanword adaptation in Korean where English targets with sonorant codas are never realized with vowel insertion, while those with obstruent codas tend to be realized with vowel insertion.

(25) English loanword adaptation in Korean

a. sonorant codas

[wul], *[wulɨ]	wool	[k^ha], *[k^harɨ]	car
[hom], *[homɨ]	home	[pɛn], *[pɛnɨ]	pen

b. obstruent codas

[sup], [sup^hɨ]	soup	[k^hisɨ]	kiss
[čɛk^hɨ]	check	[t^hjubɨ]	tube

Then, vowel insertion after a sonorant consonant is not expected given the generalization of release-to-vowel insertion in which a vowel can be inserted only after a released consonant.

Although vowel epenthesis is not expected after a sonorant consonant, internal vowel insertion did occur in sonorant-plus-sonorant sequences, taking up to 15%. Then, next question would be to investigate why internal vowel insertion unexpectedly occurred between sonorant consonants. Sonorant-plus-sonorant sequences are composed of the following three small subgroups: (i) /l/+/m/, (ii) /r/+/l/, and (iii) /r/+nasals. Among the three subgroups, internal vowel insertion exclusively occurred in words *film* and *Stockholm* of the group (i). In other words, a vowel is epenthesized only between /l/-plus-/m/ sequences. Also, target /l/ is geminated so that coda /l/ is affiliated to coda and onset of the following syllable, resulting in the syllable structure $–C_1.C_1VC_2$ (e.g., [fil.lɨm] for *film*). This unexpected syllable structure results from native Korean phonology transfer. In native Korean phonology the distribution of lateral /l/ is as follows; /l/ occurs in coda at a word boundary (e.g., [tal] 'moon') or in coda and onset at a syllable boundary ([mil.lim] 'jungle'). Then, the gemination of English /l/

in Korean-English interlanguage can be understood as the native language transfer.

Consonant deletion in sonorant-plus-sonorant sequences can be analyzed in the same way that handles sonorant-plus-obstruent sequences, as given below.

(26) C_2 deletion in sonorant-plus-sonorant sequences (e.g., girl [gər]) [4]

$-C_1C_2$	*Complex	Dep	Contiguity	Max (C_2)	Max (C_1)
a. $-C_1.C_2\mathbf{V}$		*!			
☞b. $-C_1$				*	
c. $-C_2$			*!		*
d. $-C_1\mathbf{V}C_2$		*!	*		
e. $-C_1\mathbf{V}.C_2\mathbf{V}$		*!*	*		
f. $-C_1C_2$	*!				

(27) C_1 deletion in sonorant-plus-sonorant sequences (e.g., girl [gəl])

$-C_1C_2$	*Complex	Dep	Max (C_2)	Contiguity	Max (C_1)
a. $-C_1.C_2\mathbf{V}$		*!			
b. $-C_1$			*!		
☞c. $-C_2$				*	*
d. $-C_1\mathbf{V}C_2$		*!		*	
e. $–C_1\mathbf{V}.C_2\mathbf{V}$		*!*		*	
f. $-C_1C_2$	*!				

In the tableau (26) /l/ instead of /r/ deletes in order not to violate the constraint Contiguity that rules out any modification of elements internal to the input string. Here note that Contiguity plays a decisive role in selecting the optimal form in (26). This could be regarded as a case of the emergence of the unmarked in that the otherwise inactive Contiguity constraint is active with respect to the sonorant-plus-sonorant subgroup sequences (McCarthy and Prince 1995). By contrast, in the tableau (27) /r/ deletion occurs because P-map constraint Max(C_2) which facilitates perceptual similarity of the target outranks Contiguity.

6. Conclusion

Although there have been several studies on the acquisition of English complex coda sequences in a second (foreign) language acquisition, the

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[4] Many instances of /l/ deletion in *girl* were observed. This might be due to the fact that the native speaker who participated in the transcription had a difficulty with the perception of dark [ɫ] in *girl*, as most Korean learners of English do not produce it target-appropriately and even native speakers of English have a tendency to vocalize dark [ɫ].

simplification strategies in resolving the complex clusters differ depending on studies. We suspect that the reason for the diversity in cluster-breaking strategies may come from the stimuli themselves because not all clusters are expected to behave in the same way due to the difference of their component consonants. Thus, we made a stimulus list that contains the possible full range of coda cluster sequences in English. The results have shown that simplification strategies as to insert a vowel or delete a consonant are influenced by the subgrouping of the cluster sequences. Based on the different results from each subgroup, we have provided a constraint-based analysis in conjunction with P-map.

Specifically, it has been shown that the simplification of English biconsonantal coda clusters by Korean learners results from several different sources within the framework of OT. Coda clusters are simplified because of the universal markedness constraint *Complex that prohibits complex segments. Whether the learners adopt insertion strategies or deletion strategies varies; when vowel insertion strategies are adopted, the constraint Max(segment) outranks the constraint Dep(segment) and, vice versa in consonant deletion strategies. In each strategy universal markedness, P-map effects, and language transfer effects interact with one another. If P-map effects dominate over transfer effects, a vowel is inserted in the perceptually least distinctive place in order to maximize the similarity between the target and the source. However, it is not always the case that a vowel is inserted in the least distinctive place. Sometimes a vowel may be inserted in a more perceptually salient place and this unexpected insertion site is because the constraint from the native language transfer outranks the P-map constraints, as summarized in (9).

When a consonant deletes, Dep (segment) outranks the constraint Max (segment). Standard OT can predict which consonant to delete. The survival of fricatives over coronal stops is accounted for by ranking Max(+continuant) higher than Max(-continuant). Likewise, the survival of peripheral stops over the coronal stop /t/ is accounted for by the dominance of Max(peripheral) over Max(coronal). Also, the variation as to delete a peripheral stop or a fricative is due to the alternative rankings between the constraints Max(+continuant) and Max(peripheral). This is summarized in (17).

The syllabification patterns of consonant sequences with sonorants are somewhat different from those with obstruents. This is due to the following three factors: perceptual similarity, language transfer, and universal consideration. After sonorants, a vowel is not inserted because sonorants do not involve apparent release of air. Vowel insertion after a sonorant would be perceptually too distinct from the target English. Nonetheless, a vowel is inserted specifically between the target lateral [l] and nasal [m] to break the cluster sequence and [l] is geminated to be affiliated to coda and the onset of the following syllable because /l/ in the medial position is always geminated in native phonology. Finally, the survival of one consonant over the other in coda is accounted for by the alternative ranking between the P-map constraint Max(C_2) and Contiguity.

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