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Perceptual and Articulatory Factors in Place Assimilation:

An Optimality Theoretic Approach

by

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TABLE OF CONTENTS

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ABSTRACT OF THE DISSERTATION

Perceptual and Articulatory Factors in Place Assimilation:
An Optimality Theoretic Approach

by

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Doctor of Philosophy in Linguistics
University of California, Los Angeles, 1995
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This dissertation investigates place assimilation in consonant clusters, focusing on the following two related issues: (i) to determine the articulatory and perceptual mechanisms involved in place assimilation; and (ii) to provide an explicit formal analysis for place assimilation, with special attention to crosslinguistic patterns. In the first project, we have mainly investigated the mechanisms which govern casual speech place assimilation, by exploring Korean and English *pk* clusters in experimental research. Results indicate that gestural reduction plays the decisive role in the perceptual loss of the target in place assimilation; and that the reduction process is speaker-controlled.

In the second project, we first performed a brief survey of place assimilation. The results show that crosslinguistic patterns of place assimilation suggest implicational statements; e.g. if stops are targets of place assimilation, so are nasals. To provide an explicit formal analysis for these implicational statements, we have invoked Optimality Theory (Prince and Smolensky 1993; McCarthy and Prince 1993) in which the phonology is composed of ranked violable constraints. We further assume that place assimilation is a compromise between articulatory and perceptual demands governing speech production in general (Kohler (1990) and Mohanan (1993), both of whom are originally based on Lindblom (1988, 1990)). Based on an in-depth discussion of perceptual and articulatory factors, we have proposed two conflicting groups of (perceptually and articulatorily motivated) constraints which conspire to produce the range of attested production outputs. In addition, we have proposed universal rankings for perceptually motivated constraints. We claim that different interactions of these independently motivated constraints result in the crosslinguistic patterns of place assimilation; and that the universal ranking of perceptually based constraints captures the implicational statements of place assimilation typology. We finally demonstrate how the proposed theory can deal with attested patterns of place assimilation by providing the analyses for those attested in Malayalam, English and Korean.

Chapter 1

Introduction

Place assimilation patterns display language-specific variability. For instance, in English, nasals and stops can be targeted in place assimilation, but in Malayalam, only nasals can be targeted. Crosslinguistic generalizations about place assimilation (e.g. nasals are more likely targets than stops.) suggest that certain acoustic constraints govern the range of variability: more likely targets of place assimilation are acoustically less salient than less likely ones. So, for example, nasals have acoustically less salient place cues than stops do (Ohala 1990).

In present study, we provide an explicit formal account for such variable, but constrained, patterns of place assimilation. In so doing, we propose a phonetically based theory of phonology which is a formulation of principles governing speech production in general, and not just place assimilation. Our basic assumption is that place assimilation is a compromise between articulatory and perceptual demands governing speech production, i.e. 'minimization of articulatory effort' and 'maximization of perceptual contrasts' respectively (from Kohler (1990) and Mohanan (1993), both of whom are originally based on Lindblom (1988, 1990)).

Specifically, employing Optimality Theory (Prince and Smolensky 1993; McCarthy and Prince 1993) in which the phonology is composed of ranked violable constraints, we propose two conflicting groups of constraints which formulate the two demands governing speech production. These two groups of constraints, which conspire to produce the range of attested production outputs, have opposite effects regarding place assimilation. Articulatorily motivated constraints have the effect of reducing or eliminating consonantal gestures, which may lead to place assimilation in consonant clusters. In contrast, perceptually motivated constraints have the effect of preserving consonantal gestures, thus resisting place assimilation. Diverse ways of reconciling these two groups of conflicting constraints lead to language-specific patterns of place assimilation.

In addition, we propose universal rankings of perceptually motivated constraints which formally characterize the hypothesis that more articulatory effort is likely to be invested in the production of sounds with powerful acoustic cues than those with weak cues (Kohler 1990, 1991, 1992; Steriade 1992 and Byrd 1994). This hypothesis accounts for attested crosslinguistic patterns of place assimilation: segments with acoustically weak place cues are more likely to suffer the effects of articulatory reduction, thus more likely targeted in place assimilation, than those with acoustically salient cues. Consequently, the universal rankings capture crosslinguistic generalizations on place assimilation.

In the following sections of this Chapter, we consider, in turn, (i) the subject of the present study, (ii) purposes and issues, and (iii) the theoretical framework that the present study employs.

1.1 Place Assimilation

Place assimilation in consonant clusters involves one constituent of the cluster assimilating in point of articulation to a neighboring constituent. For example, in English, if a word-final coronal stop or nasal is followed by a noncoronal consonant, the former optionally assimilates in place to the latter:

(1)

a.	'right call'	/rajt kɔl/	-->	[rajk kɔl]
b.	'phone book'	/fon bʊk/	-->	[fom bʊk]

Place assimilation always involves loss of the gesture encoding place of articulation in the target segment (2a) and lengthening the corresponding gesture in the trigger segment (2b), as shown in the following simplified format:

(2)	Input	C_1C_2	
a.	<u>loss of target</u>	Ø	
b.	<u>lengthening of trigger</u>	C_2C_2	(Output)

(e.g.)	Input	/raj t k ɔl/	'right call'
	<u>loss of target</u>	raj Ø	
	<u>lengthening of trigger</u>	k k ɔl	
	Output	[raj k k ɔl]	

There are three parameters for classifying patterns of place assimilation: (i) place assimilation can be classified as either *local* or *non-local* depending on whether it occurs between adjacent or non-adjacent segments; (ii) place assimilation can be either *regressive* or *progressive* depending on the direction of spreading; (iii) place assimilation can occur either *within the same articulator* (e.g. s..š --> š...š) or also *across articulators* (e.g. np --> mp; nk --> ŋk; nf --> ɱf; ng --> ŋg). Among these varieties, we focus on local, regressive, cross-articulatory assimilations, although reference to the other types is made when necessary.

1.2 Purposes and Issues

The purposes of the present study are the following:

(3) a. to determine the *articulatory* and *perceptual mechanisms* involved in place assimilation;

b. (based on the results of (a)) to provide an *explicit formal analysis* for place assimilation, with special attention to crosslinguistic patterns.

We now present specific issues related to (3a) and (3b). Also, problems with previous approaches to the issues are discussed.

1.2.1 Mechanism

Varieties of place assimilation fall into two major types, *categorical* and *gradient*, depending on whether the loss of an articulatory target is complete or partial.

Categorical place assimilation includes canonical patterns such as morphophonemic alternations (4a) and historical changes (4b):

(4)

a. English i[n]+ept vs. i[m]+possible

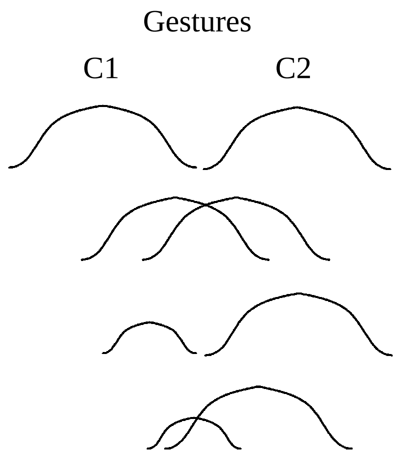
b. Latin scriptu >> Italian scritto (Ohala 1990:258)

In these changes, the loss of the target gesture, which is accompanied by lengthening of the trigger gesture, is complete. Thus, the changes involved can be characterized by phoneme substitution. This type of place assimilation is insensitive to the speech rate and style.

In contrast, gradient place assimilation is sensitive to these factors. As shown in (1b), in the casual speech pronunciation of an English phrase, phone book, the word-final [n] alternates with [m]. However, the phonetic realization of the assimilated word-final /n/ is not exactly the same as that of /m/; the change is often incomplete. As shown in several studies (Barry 1985, 1991; Browman and Goldstein 1990; Nolan 1992, and Byrd 1994), residual gestures of a target segment in casual speech place assimilation are often observed. Thus, this gradient change is not equivalent to phoneme substitution.

Between the two types of place assimilation, it seems that the gradient place assimilation which typically occurs in casual speech involves more complicated articulatory and perceptual mechanisms than the categorical assimilation. In categorical assimilation, the target gesture completely deletes, and, of course, is inaudible. In contrast, as claimed by Browman and Goldstein (1990), in gradient assimilation, the articulatory target gesture may not be eliminated; its loss is perceptual. There are three logical possibilities about the articulatory process which is responsible for the loss of the target in gradient casual speech assimilation: gestural overlap (5b), gestural reduction (5c), or a combination of the two (5d).

(5) C1C2 --> C2C2



a. Neither overlap nor reduction

b. Temporal overlap of C1 and C2

c. Spatio-temporal reduction of C1

d. Combination of b and c

In the discussion which follows, we are mainly concerned with the comparison between (5b) and (5c), focusing on the question of which articulatory process (gestural overlap or gestural reduction) plays the main role in the perceptual loss of the target.

An account which is mainly based on gestural overlap has been proposed by Browman and Goldstein (1990). In these authors' account, casual-speech place assimilation is hypothesized to result from the increased overlap of gestures as schematized in (5b). For instance, in the casual speech alternation of the English phrase 'hundred pounds' shown in (6), /p/ is considered superimposed on /d/, with the /d/ gesture maintained.

(6) Browman and Goldstein (1990:359)

/hʌndrəd 'paʊndz/ --> [hʌndrəb 'paʊndz] ("hundred pounds")

"The bilabial closure gesture may increase its overlap with the preceding alveolar gesture, rendering it effectively inaudible. The overlap of voicing onto the beginning of the bilabial closure yields the [bp] transcription" (Browman and Goldstein 1990:361). In sum, within this overlap-based account, perceptual loss of the target gesture in casual-speech place assimilation results from a marked overlap of target and trigger gestures.

In contrast, as schematized in (5c), we may hypothesize that reduction of the target gesture gives rise to the perceptual loss of the target in gradient place assimilation. If an articulatory gesture reduces in duration and magnitude, it may not produce acoustic effects for its perception -- even when its reduction falls short of complete elimination. This gestural reduction, which is necessarily accompanied by acoustic weakening, may be considered the source of the perceptual loss of the target in gradient casual-speech assimilation. Within the reduction-based account, there is a further issue which needs to be resolved; i.e. whether the reduction is controlled by speakers or by vocal tract constraints.

Let us summarize the issues about articulatory and perceptual mechanisms of gradient place assimilation:

(7) a. Is gestural overlap or gestural reduction responsible for the perceptual loss of the target gesture?

b. If gestural reduction is the process, is it speaker-controlled or not?

To tackle these issues, I investigated English and Korean labial-velar clusters by employing oral pressure experiments. Results show that gestural overlap alone cannot give rise to perceptual place assimilaton; instead, gestural reduction does. Furthermore, the gestural reduction is speaker-controlled. These experiments are presented in full in Chapter Three.

1.2.2 Formalization

Formal accounts of place assimilation have been proposed in many, if not all, phonological approaches. However, it seems that no previous theories have been successful in explaining all properties characterizing place assimilation.

Let us first list the facts characterizing place assimilation and then discuss which of them can be and cannot be accounted for in the previous approaches. First, different languages display different patterns of place assimilation. For instance, in English and Korean, both nasals and stops can be targeted in place assimilation, but in

Hindi and Malayalam, only nasals can be targeted. Also, in all these languages, place assimilation is only regressive, but German displays not only regressive but also progressive place assimilation in casual speech. (See the discussion in Chapter Two for the relevant facts.) In sum, attested patterns of place assimilation display language-specific variability.

However, as shown and discussed by Mohanan (1993), such variable language-specific patterns are subject to certain crosslinguistic generalizations; e.g. (i) nasals are more likely targets than stops, and (ii) codas are more likely targets than onsets. From these generalizations, the corresponding implicational statements can follow: (i) if stops are targets, then so are nasals, and (ii) if onsets are targets, then so are codas. Moreover, these crosslinguistic generalizations (and implicational statements derived from them) are phonetically grounded; i.e. acoustically less salient segments are more likely targets in place assimilation than acoustically more salient segments (Ohala 1990, and Kohler 1991 among others). As stated by Ohala (1990:261) citing Winitz, Scheib, and Reeds (1972), House (1957) and Malécot (1956) among others, place cues for stops, especially when released, are generally very strong, whereas nasals have weak place cues, especially when preceding stops; in addition, CV transitions are perceptually stronger than VC transitions, which explains the perceptual strength of onsets over codas. (Crosslinguistic generalizations of place assimilation and their related acoustic correlations, some of which have just been outlined, are fully discussed in Ch. 2 and Ch. 4 respectively.)

In addition, a theory of place assimilation must be able to provide a correct description of the articulatory process yielding place assimilation. As mentioned above, loss of the target gesture in gradient place assimilation is not complete. This gradient characteristic needs to be captured in a theory of place assimilation. In summary, a theory of place assimilation must explain the following:

(8) a. Language-specific variability

b. Implicational statements

c. Phonetic motivation underlying (b)

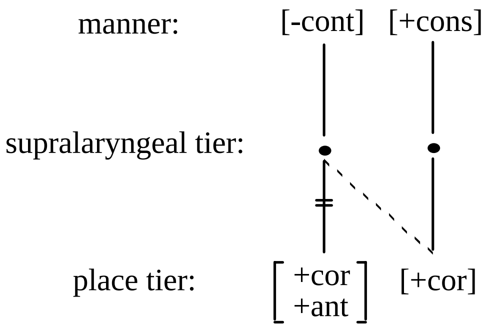
d. Gradiency (of gradient place assimilation)

These facts can serve as criteria to evaluate theories which attempt to provide an explicit analysis for consonant place assimilation. An approach which fails to capture any of the above can not be considered a successful theory of place assimilation. Let us now consider some previous approaches to place assimilation, focusing on how they deal with the facts summarized in (8).

1.2.2.1 Autosegmental Phonology

The autosegmental formulation of place assimilation which has been established in Goldsmith (1976, 1979), Halle and Vergnaud (1980), Steriade (1982), Clements (1985) and Hayes (1986) implies discrete and categorical operations on node association. The following representation is given by Clements to describe the place assimilation of English coronal stops to a following coronal consonant (e.g. tenth [tɛn̪θ]):

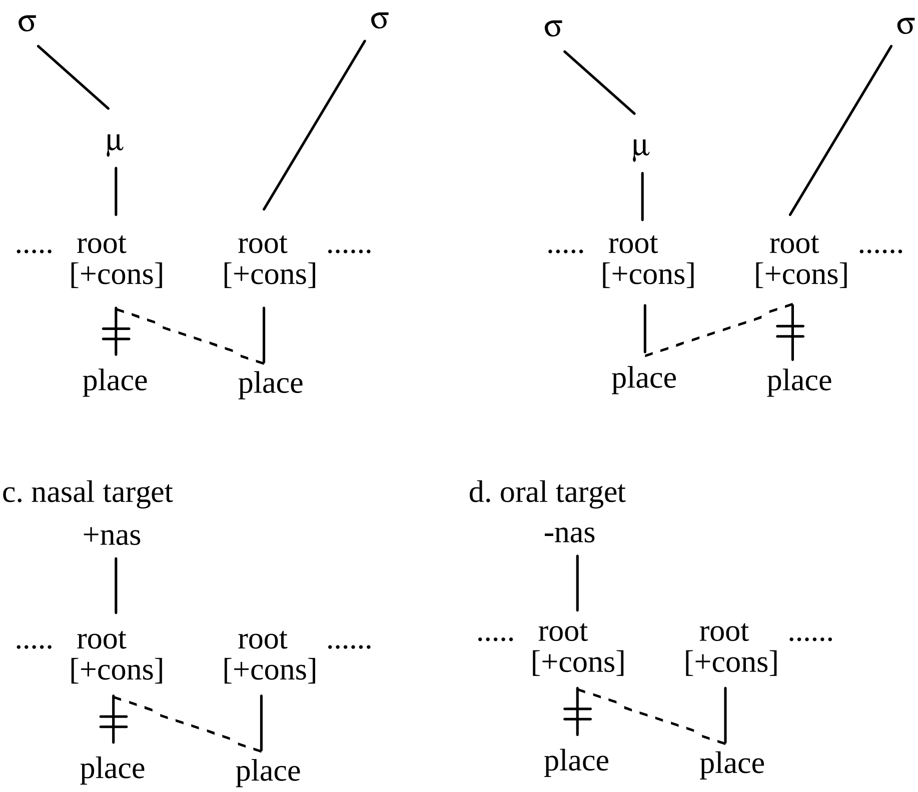
(9) (Clements 1985:236 #12)



This representation is interpreted in the following way: if the first segment has [-cont] in the manner tier and [+cor, +ant] in the place tier, and the second segment has [+cons] in the manner tier and [+cor] in the place tier, then delink the original association line between supralaryngeal and place tiers of the first segment and introduce the new association line between the supralaryngeal node of the first segment and the place node of the second segment.

In this approach, language-specific patterns of place assimilation are captured by different feature trees. However, there is no way to capture the crosslinguistic generalizations of place assimilation alluded to earlier, not to mention the phonetic motivation which underlie them. Adopting somewhat simplified formulation, we can provide the following autosegmental representations for place assimilations where a coda, an onset, a nasal, and an oral consonant are targeted:

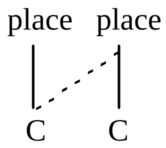
(10) a. coda target b. onset target



Neither the representation itself nor its associated interpretation captures the fact that (10a) is more natural than (10b) and that (10c) is more natural than (10d). This generalization can only be stipulated. Therefore, the autosegmental formulation fails to capture crosslinguistic generalizations on place assimilation and their related phonetic motivation (8b,c).

Gradiency of gradient place assimilation (8d) is also problematic in autosegmental phonology. Delinking the original association line and spreading a new one can only be interpreted in a categorical way. Thus, the autosegmental formulation, shown in (9) and (10), predicts no surface remnants of the target gesture since the originally associated place is delinked. As discussed by Nolan (1992), we can consider the following revised format for gradient place assimilation:

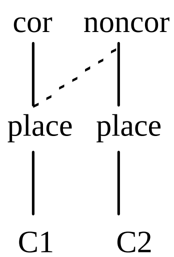
(11)



This representation is different from the original format in that a new association line is entered without loss of the original association line. Maintaining the original association line is meant to capture residual gestures of the target consonant. However, as Nolan points out, the representation in (11) does not characterize the fact that the target segments are reduced. To get the effect of a weakened target segment, we have to interpret the original association line as weaker than the newly-entered line. The association lines involved should have equal strength, and so it would be implausible to interpret a newly-entered association line as stronger than the original association line. The two association lines involved, the newly-entered line and the original one, would produce a simultaneous double articulation instead of a weakened segment.

In a commentary on Nolan's work, Hayes (1992) attempts to resolve this problem, proposing a slightly modified formulation. The following representation for English postlexical place assimilation follows Hayes's account:

(12)



Hayes first claims that the representation (11) is "qualitatively incorrect," since it would actually derive "a contour segment," not a doubly articulated segment. This seems to be based on the assumption that elements of the same sort cannot be simultaneous. He instead adopts a representation (12) which is meant to derive a doubly articulated segment C1: since the place node of C1 dominates two distinct articulator nodes, these may be interpreted as simultaneous according to Sagey's (1986) theory of segmental contours. Hayes divides English postlexical place assimilation into two processes, each at a distinct level: phonological place assimilation represented in (12) and phonetic alveolar weakening shown in (13).

(13) Alveolar Weakening (Hayes 1992:284)

Depending on rate and casualness of speech, lessen the degree of closure for a COR autosegment, if it is [-continuant] and syllable-final.

More specifically, 'place assimilation proper' (Hayes's terminology) is spreading the articulator node of an obstruent onto a preceding coronal coda stop. This spreading rule derives a doubly articulated, corono-dorsal or corono-labial, segment. In turn, this derived doubly-articulated segment will be subject to the independent phonetic rule which gradually weakens alveolar closures in syllable-final position. Thus, it is the phonetic weakening rule which will explain the gradiency of postlexical place assimilation.

In Hayes's account, place assimilation proper and alveolar coda weakening are not related in any sense. The spreading rule (12) applies independently of the alveolar weakening (13). The spreading rule (12) has the effect of lengthening the noncoronal in the coronal-noncoronal consonant cluster. Also, the alveolar weakening rule (13) has the effect of reducing the coronal gradually in the coronal-noncoronal cluster. If the speading rule (12) is independent of alveolar coda weakening (13), then the noncoronal in the coronal-noncoronal cluster would always be long, regardless of the degree of coronal coda reduction. However, as shown in Barry's (1991) electropalatographic study on English postlexical place assimilation, as the first stop in a coronal-noncoronal stop cluster reduces in time, the second stop lengthens. (See section 4.2.2 for more detailed discussion.) In other words, how much the noncoronal in the coronal-noncoronal cluster lengthens depends on how much the coronal reduces. The lengthening and the reduction are compensatory.

Thus, 'place assimilation proper', i.e. (12), is not independent of alveolar weakening (13), although Hayes's claim may still be correct in that alveolar weakening can occur independently of place assimilation. (Based on this one-way independence of the alveolar weakening from the 'place assimilation proper', we provide an analysis of English postlexical place assimilation in section 4.3.2.) This compensatory lengthening effect cannot be captured in Hayes's account in which spreading the noncoronal and reducing the coronal in the coronal-noncoronal cluster are completely independent of each other. In sum, Hayes's revision does not save the autosegmental formulation for gradient postlexical place assimilation.

In conclusion, as discussed above, the autosegmental formulation fails to capture most important facts about place assimilation (8b,c,d).

1.2.2.2 CORONAL UNDERSPECIFICATION

A number of authors (Kiparsky 1985; Cho 1990; Shaw 1991; Yip 1991; Paradis and Prunet 1991; and others) claim that coronals represent the unmarked place of articulation in consonants.[1]

> The third requisite for our proposal to work out is some way to refer to unmarked segments such as coronals in the lexical phonology. By our assumption coronals are not associated with a [+coronal] melody in the lexical phonology...[coronals] can be referred to as consonants that have no specification on the tier of place features. (Kiparsky 1985:98)

The hypothesis that alveolars are unmarked as to point-of-articulation features is based on the following crosslinguistic patterns:

(i) They are the most frequently chosen segments in phoneme inventories;

(ii) "In sound change they also stand out from the labials and velars because they

---

[1]Between the two versions of Underspecification theory, only Radical Underspecification (first proposed by Archangeli 1984) is relevant to the purpose of this section. This is because underspecification on coronals will be severely restricted within the theory of Contrastive Underspecification (Steriade 1987; Mester and Ito 1989 and others), which claims that only non-distinctive feature values may be underspecified.

are more liable to assimilate the point of articulation of a neighboring consonant and to appear as the product of neutralization in syllable codas." (Paradis and Prunet 1991: xiii);

(iii) They may more frequently form a heterorganic consonant cluster, compared with velars and labials (Yip 1991).

If alveolar coronals are universally unmarked as to point of articulation, then, it is further assumed, Universal Grammar equips individual languages with Redundancy Rules expressing this fact:

(14)
a. [ ] --> [coronal]

b. [coronal] --> [coronal]
|
[+anterior]

The first Redundancy Rule (14a) indicates that the default articulator is coronal; the second rule (14b) indicates that the default dependent of [coronal] is [+anterior]. Given the Redundancy Rules, it is possible to assume that the alveolars are placeless in the underlying representation. This assumption of placeless coronals appears to account for the asymmetric behavior of coronals shown in (15). To illustrate how, we summarize Cho's (1990) analysis of Sino-Japanese place assimilation.

(15) Sino-Japanese place assimilation (examples chosen from Cho 1990 pp.55-56)

Coronals are targets

a. bet + taku --> bettaku 'detached villa'

b. bet + kaku --> bekkaku 'different style'

c. bet + puu --> beppuu 'separate cover'

Noncoronals are not targets

d. gak + ko --> gakko 'school'

e. gak + see	-->	(*gassee)	'student'
		gakusee	
f. gak + cyoo	-->	(*gacycyoo)	'school president'
		gakucyoo	
g. gak + mon	-->	(*gapmon)	'learning'
		gakumon	

Word-final coronal /t/ assimilates in place to following word-initial consonants as in (15b-c), whereas word-final noncoronal /k/ does not assimilate to following word-initial consonants (15e-g); instead, the vowel /u/ is epenthesized to avoid a heterorganic consonant cluster. (Different descriptive analysis for the fact in (15) will be shown and followed in section 2.1.)

In the underlying representations of Japanese, dentals are hypothesized by Cho to lack a place node, whereas velars and labials contain a place specification:

```
(16)  a.  /t/      b.   /k/        c.   /p/
          root          root            root
                          |               |
                        place           place
                          |               |
                        dorsal          labial
```

If a dental is followed by a consonant with a place specified as in *bet* + *puu*, the underspecified dental consonant will get a place specification from a following consonant, producing a geminate noncoronal consonant as in *beppuu*.

(17)

```
/t/        /p/                  [p]      [p]

root      root     ------>     root     root
            |       place         \     /
          place   spreading        place
            |                        |
          labial                   labial
```

In contrast, if a noncoronal consonant is followed by another noncoronal consonant as in (15g) *gak + mon*, the place spreading will be blocked by Structure Preservation since it would produce a doubly-linked place structure:

(18)

```
     /k/      /m/                     *[k͡p]     [m]

    root     root            ------>     root     root
     |        |    \          place        |   \   |     \
   place   place[+nas]    spreading    place place [+nas]
     |        |                            |        |
   dorsal   labial                      dorsal labial
```

The hypothesis of coronal underspecification seems appropriate in dealing with the special behavior of coronals in place assimilation: in many cases, coronals tend to be the only target and the only non-trigger of place assimilation. The underspecificationist reasoning can be summarized as follows: coronals are placeless when assimilation applies. Being placeless, they cannot trigger place spread. Being placeless, they are the only segments that can undergo a feature-filling application of place assimilation. Cho (1990) and others following Radical Underspecification obviously assume that either all assimilations are feature-filling or, at least, that those in which coronals pattern as asymmetric targets are feature-filling. However, there are several problems within this approach which we will now outline.

First, as discussed in Kaun (1993), the theory of Radical Underspecification makes incorrect predictions with respect to the pattern of coronal assimilation rules. The problems emerge in the analysis of phenomena such as consonant harmony and cross-consonantal vowel assimilation. We summarize here only her discussion of Catalan nasal assimilation, since the Catalan data have been adduced as evidence for the idea that coronals are an asymmetric target of place assimilation (Kiparsky 1985).

In Catalan, /n/ assimilates in place to a following consonant. (See section 2.1 for more detailed discussion of Catalan place assimilation.)

(19) (Kiparsky 1985:95)

unassimilated alveolar:	so[n] amics	'they are friends'
labial:	so[m] pocs	'they are few'
labiodental:	so[ɱ] feliços	'they are happy'
dental:	so[n̪] dos	'they are two'
alveolar:	so[n] sincers	'they are sincere'
postalveolar:	so[n̩] rics	'they are rich'
laminopalatal:	so[n,] [ž]ermans	'they are brothers'
palatal:	so[n,] [ʎ]iures	'they are free'
velar:	so[ŋ] grans	'they are big'

The other nasals do not display cross-articulator assimilation: /m/ assimilates only to a following labiodental, and /ŋ/ and /ɲ/ do not assimilate at all:

(20) (Kiparsky 1985:95)

/m/:	so[m] amics	'we are friends'
	so[m] pocs	'we are few'
	so[ɱ] feliços	'we are happy'
	so[m] dos	'we are two'
	etc.	
/ŋ/, /ɲ/:	ti[ŋ] pa	'I have bread'
	a[ɲ] feliç	'happy year'
	etc.	

Kiparsky attributes this special behavior of coronals to their underspecified status.

> Turning to the Nasal Assimilation process itself, the outstanding question that we wish to answer is why only the coronals assimilate to all places of articulation, while the labials assimilate only in a limited way and the palatals and velars do not assimilate at all, as seen in the data of (20)-(21) [(19)-(20) above]. The answer, again, is that the coronal nasals, being unmarked, are unspecified for place of articulation when Nasal Assimilation applies, and that Nasal Assimilation associates specified (and therefore marked) feature values or autosegments with segments that do not carry those feature values or autosegments. (Kiparsky 1985:97)

The rule which interacts with Nasal Assimilation is Cluster Simplification; a rule which deletes a stop after a homorganic, tautosyllabic consonant.

(21) (Kiparsky 1985:95)

a. [kamp]	[es]	-->	kam es	'the field is '
b. [kamp]	[sigi]	-->	kam sigi	'the field were (subj.)'
c. [kamp]		-->	kam	'the field'

Kiparsky argues that this simplification applies only to homorganic clusters:

(22) (Kiparsky 1985:95)

a. subject to Cluster Simplification: mp, nt, lt, ŋk, rt, st

b. not subject to Cluster Simplification: lp, lk, rp, rk, sp, sk

Simplification is formulated below, after Kiparsky's (1985), as the delinking of the second C from the homorganic cluster:

(23) Cluster Simplification (Kiparsky 1985:96)

```
[place features]
      / \
     C   C
      \  ≠
       σ
```

Cluster Simplification interacts with Nasal Assimilation:

(24) (Kiparsky 1985:96)

a.	/kaNp/	-->	kamp	-->	kam	'field'
b.	/bɛNk/	-->	bɛŋk	-->	bɛŋ	'I sell'
c.	/biNt/	-->	bint	-->	bin	'twenty'

Two important points should be noted: "(i) Nasal Assimilation precedes Consonant Cluster Reduction and (ii) A sequence of two coronal consonants is targeted by Consonant Cluster Reduction" (Kaun 1993:76). For coronal consonant clusters to undergo the Cluster Reduction, they must have been assigned [+coronal] already. However, [+coronal] is not supposed to be assigned in the lexical component where Cluster Reduction applies. Thus, coronals should not undergo Cluster Reduction, contrary to the hypothesis.

Putting this problem aside, we may simply assume that a Redundancy Rule assigns [+coronal] at the lexical level. Then, the interaction between Nasal Assimilation and Cluster Reduction is as follows:

(25) (from Kaun p.77 #18)

Lexical Level:	/biNt/	/kaNp/ | LAB
Nasal Assimilation	-----	kamp \/ LAB
Default [+coronal] specification	bint \/ COR	-----
Cluster Reduction	bin	kam

Nasal Assimilation also applies postlexically; e.g. venc vint pans [bɛ́ŋ bím páns] 'I sell twenty loaves of bread'. The derivation would be as follows:

(26) (from Kaun p.77 #19; the output of nasal assimilation is in boldface)

	/ bɛNk	biNt	paNs /
LEXICAL			
Nasal Assimilation	bɛ**ŋ**k		
Cluster Simplification	bɛŋ_	bin_[2]	
POSTLEXICAL			
Nasal Assimilation		bi**m**	

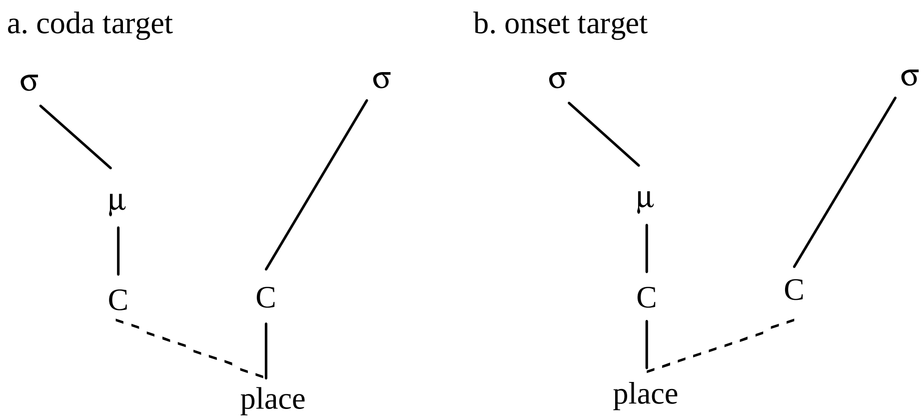
We now have two types of Nasal Assimilation: at the lexical level, Nasal Assimilation applies in a feature-filling manner; at the postlexical level, it applies in the feature-changing manner. Within this analysis, Kiparsky's original explanation for the special status of coronals must be abandoned. At the postlexical level, the coronal nasal, which is the target of Nasal Assimilation, is specified as [+coronal]:

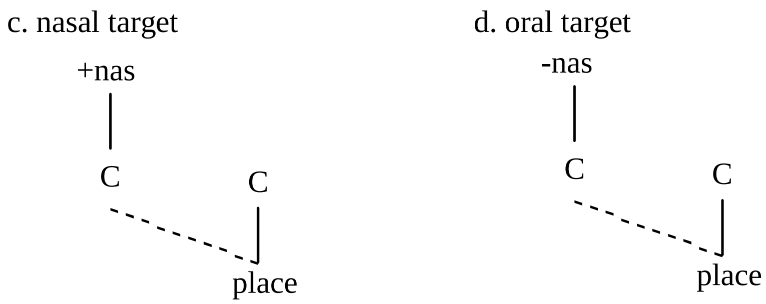
[2] This is written as biN__ in Kaun (p.77); we think this is a mistake.

thus, coronals should not be a target of place spreading, for the same reason labials and dorsals cannot be targets of place spreading. Based on the above discussion, Kaun (1993) concludes that Catalan Nasal Assimilation does not support the Radical Underspecification.

Let us now discuss how place assimilation facts in (8) can be dealt with within the theory of coronal underspecification. As discussed above, coronal underspecification can capture two crosslinguistic generalizations of place assimilation; i.e. (i) coronals are more likely targets than noncoronals, and (ii) coronals are less likely triggers than noncoronals. However, coronal underspecification are subject to the same problems discussed in section 1.2.2.1 as autosegmental phonology in capturing the other generalizations (and phonetic motivations which underlie them). If we follow the main hypothesis of coronal underspecification, i.e. that coronals are common targets in place assimilation because they are placeless, we expect that not only coronal-noncoronal clusters but also noncoronal-coronal ones would likely undergo place assimilation; and also that nasal and nonnasal coronals would likely undergo assimilation to about the same extent. These expectations do not agree with the crosslinguistic fact that (coronal) codas and nasals are much more common targets in place assimilation than (coronal) onsets and nonnasals respectively.

(27)

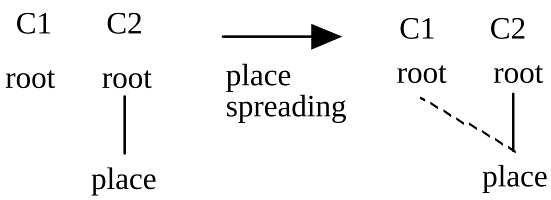




There is no a priori reason why (27a) is more natural than (27b) and that (27c) is more natural than (27d). In other words, there is no way to capture that (coronal) codas are more likely targets than (coronal) onsets; and that (coronal) nasals are more likely targets than (coronal) nonnasal stops. It seems that coronal underspecification is no better than autosegmental phonology in explaining crosslinguistic generalizations on place assimilation.

In addition, gradient place assimilation is as problematic with coronal underspecification as with autosegmental phonology. The underspecification analysis cannnot explain, in a unified fashion, the fact that coronals are preferred targets both in categorical assimilation and in gradient assimilation: e.g. in English and Russian, only coronals can be targeted in gradient place assimilation (Barry 1991). The approach assuming underspecification on coronals always predicts complete assimilation of coronals to a following consonant since coronals do not have place at the relevant point in the derivation. In an analysis of place assimilation, most, if not all, theories of underspecification characterize the target as placeless; thus, target segments receive a place specification from the adjacent segment. This feature-filling mode of application can be illustrated in the following simplified representation which is typical in theories of underspecification:

(28)



As can be seen, the target consonant, i.e. C1 above, lacks a place component underlyingly; thus at the surface, no remnants of the target segment can remain. Thus, this feature-filling analysis cannot capture often-observed residual gestures of the target segment in gradient place assimilation. Consequently, coronal underspecification does not provide an effective framework in dealing with the place assimilation facts, i.e. most of (8b) and (8c,d).

Finally, we are in a position to discuss problems with Yip's proposal about the freedom of coronals in heterorganic consonant clusters. It has been noted in the recent literature (Steriade 1982; Ito 1986; Prince 1984; and Yip 1991) that homorganic and geminate consonant clusters are common whereas heterorganic clusters are less often attested. Interestingly, many of the languages where the majority of the consonant clusters consist of geminate or homorganic sequences also allow a limited set of heterorganic clusters in which one segment is a coronal: English, Menomini, Diola Fogny, Attic Greek, Japanese, Finnish, etc. belong in this category (e.g. in Attic Greek, tt, pp, nt, mp, pt, kt are attested whereas *pk, *mk are not.). Frequently, the coronal+C or C+coronal clusters are the only heterorganic sequences allowed in such languages. These observations lead Yip (1991) to argue that "freedom of occurrence of coronals, geminates, and homorganic clusters has a common explanation: their lack of place features." Specifically, if coronals lack place features, they can form clusters with consonants retaining place features, abiding by Yip's Cluster Condition which explains the parametric variations of adjacent consonants:

(29) Cluster Condition: Adjacent consonants are limited to a single place specification.

However, none of the languages mentioned above, which support (29), display the simplest pattern predicted by Yip's theory:

(30) a. geminates b. homorganic clusters

c. coronal stop+C clusters d. C+coronal stop clusters

e.g. a cluster inventory including pt, tp, pp, tt, kt, tk, kk and mp

According to Yip's hypothesis, all these types of clusters will be limited to a single place specification. But, in fact, no language which displays the freedom of coronals in heterorganic consonant clusters allows both (30c) and (30d). The position of coronals relative to consonants with other places is always fixed. To describe this asymmetric ordering, extra stipulations are always required in Yip's analysis. For instance, in English, Yip's proposal requires a place assignment rule stating "Associate Place with leftmost [-cont] consonant, otherwise with rightmost consonant" (p.64). Its effect will be that the leftmost stop will be the only non-coronal. If coronals are placeless and so they can freely form a heterorganic consonant cluster, obeying the Cluster Condition (29), there is no reason why their position within the cluster is always fixed, as in either (30c) or (30d). Thus, this lack of the simplest pattern predicted by Yip's proposal may undermine the validity of her major assumption, i.e. coronals are placeless at least in languages where coronals enjoy special freedom of occurrence.

Another problem for Yip's proposal involves cases in which two distinct coronals enjoy equal freedom of occurrence. Such cases are pointed out by McCarthy and Taub (1992:365): e.g. "under the influence of loan words [in English], the set of initial *s*C clusters is being extended to *ʃ*C as well: schmaltz, shpiel, schlock, shtick." The distinct alveolar /s/ and palato-alveolar /ʃ/ are allowed to form a cluster with a following consonant. If, as Yip argues, coronals lack place features, how would /s/ and /ʃ/ be underlyingly distinct segments? They contrast only in [anterior] and [distributed], which are assumed to be dependents of the coronal node. Due to these problems, Yip's proposal does not provide a plausible account for the fact; thus it does not support the placeless coronal hypothesis.

We must conclude therefore that the approach assuming the underspecification of coronals fails to provide an explicit account for the characteristic properties of place assimilation. See Steriade (1993a) for detailed discussion of further problems with underspecification theory's analysis of place assimilation. She (pp.12-13) points out that the Catalan analysis given by Kiparsky (1985) is based on a rule ordering stipulation, not the hypothesis of coronal underspecification. She also discusses several cases which suggest that it cannot be true that the entire class of alveolar coronals is place unspecified and that the very idea of underspecification -- either radical or contrastive -- fails to explain the paradigms discussed (her sections 3.3.1, 3.3.2). See also McCarthy and Taub (1992) for further discussion of empirical difficulties with the idea that alveolar coronals are placeless.

1.2.2.3 Articulatory Phonology

Many of the cases of place assimilation discussed here have been analyzed by Browman and Goldstein (1986; 1989; 1990; 1992) in the framework of Articulatory Phonology. We now discuss the assumptions of Articulatory Phonology that will be adopted here, and the respects in which my assumptions depart from those of Browman and Goldstein.

Browman and Goldstein provide a computationally explicit phonological framework based on dynamically defined articulatory gestures. Their basic assumption is "that much phonological organization arises from constraints imposed by physical systems" (Browman and Goldstein 1990:341). If we accept their assumption that many phonological phenomena are phonetically based, Articulatory Phonology offers a promising framework for incorporating phonetic naturalness into phonological theory. As we will see in the next section, we agree with these authors in that a theory of place assimilation must be based on principles governing phonetics. This may lead us to capture universal facts about place assimilation which are governed by phonetic naturalness, i.e. implicational statements (8b) and the phonetic motivation underlying them (8c).

However, we depart from Articulatory Phonology in specific points of how to analyze place assimilation. Within Articulatory Phonology, casual speech alternations such as English postlexical place assimilation are analyzed as consequences of variation in the overlap and magnitude of gestures. As discussed above with (6), gestural overlap is employed as a central mechanism in explaining casual speech alternations including place assimilation, although gestural reduction is an explanatory option as well. It has been successful in accounting for gradient place assimilation since gestural overlap is inherently gradient. However, as we see in Chapter Three, gestural reduction plays more decisive role in at least some cases of casual speech place assimilation than gestural overlap; further, the reduction is controlled by speakers, not by vocal tract constraints. The same claim has been made by Nolan (1992) and Barry (1992). Notice that Articulatory Phonology emphasizes the role of vocal tract constraints in casual speech alternations rather than the role of speaker-controlled variation. In sum, we agree with Articulatory Phonology in its general idea: casual speech place assimilation must be the result of applying some changes to articulatory gestures. However, we depart from the theory in emphasizing the role of gestural reduction as well as the role of speakers in this reduction. (See papers in Phonetica, Volume 49 for a detailed discussion of Articulatory Phonology.)

1.3 THEORETICAL FRAMEWORK - OPTIMALITY THEORY

Let us detail the theoretical framework and assumptions that the present study employs in proposing an explicit formal account of crosslinguistic patterns of place assimilation. The present study employs Optimality Theory (Prince and Smolensky 1993; McCarthy and Prince 1993) as the main framework. In Optimality Theory, the phonology is composed of sets of ranked and violable constraints. The correct output is the one which best satisfies the constraints. All constraints are universal; but rankings are language-specific. Thus, individual grammars are formed by ranking constraints in a particular way. For instance, suppose that there are two languages, L1 and L2, which avoid consonant clusters in a different manner: one constituent of the cluster deletes in L1, and a vowel is epenthesized in L2. We can focus on the following three active constraints:

(31) (From Prince and Smolensky p.85)

a. -COD

Syllables must not have a coda.

b. PARSE

Underlying segments must be parsed into syllable structure.

c. FILL

Syllable positions must be filled with underlying segments.

In both languages, -COD is dominant in ranking; then, sequences including intervocalic consonant cluster (-VC.CV-) will not be allowed in the surface. But, different rankings with respect to the other two constraints will explain the different patterns attested in the two languages, L1, 2. The table in (32) shows how the constraints interact to produce the optimal output in L1. Following Prince and Smolensky, we adopt the following conventions. An empty cell indicates that the corresponding constraint is satisfied, whereas a star indicates violation. The symbol ☞ indicates the optimal output. Solid vertical line indicates that the constraint on its left side dominates the one on its right side; weak vertical line indicates a tie in ranking. And, < > indicates that the segment within it is unparsed, subject to Stray Erasure (Steriade 1982). indicates empty structural position of a syllable which will be filled with the default segment.

(32) L1 (C-deletion)

/-VCCV-/	-COD	FILL	PARSE
-VC.CV-	*		
-V.C .CV-		*	
☞ -V<C>.CV-			*

In L1, both -COD and FILL dominate the PARSE. In the first candidate, a coda consonant is posited, violating the -COD. In the second candidate, an empty structure for an epenthetic vowel occurs between the consonants, violating the FILL. The final candidate violates the PARSE, since one underlying consonant within it is unparsed, subject to deletion. The PARSE is ranked below -COD and FILL; thus, the final candidate commits the least degree of the violation for the constraints, being the optimal output. In sum, the language-specific ranking, i.e. -COD, FILL >> PARSE, explains the consonant deletion in L1.

In contrast, L2 employs the reverse ranking in which the PARSE (and -COD) dominates FILL.

(33) L2 (V-epenthesis)

/-VCCV-/	-COD	PARSE	FILL
-VC.CV-	*		
-V<C>.CV-		*	
☞ -V.C .CV-			*

In the first candidate, a coda is posited, violating the -COD. In the second candidate, one consonant is unparsed, violating the PARSE. The final candidate violates the FILL, since an empty structure for an epenthetic vowel is posited. The FILL is ranked below -COD and PARSE; thus, the final candidate best satisfies the constraints, being the optimal output. In sum, for the sake of -COD and PARSE, the violation of FILL needs to be tolerated, allowing an empty structure for an epenthetic vowel.

As we have just seen, under Optimality Theory, the typology of a phonological phenomenon can be understood as the scope of reranking the universal constraints which conspire to produce the phenomenon. We should ask then what constraints and what fixed rankings determine the typological pattern of place assimilation? Two basic groups of constraints fall out from the following assumption advanced by Kohler (1990) and Mohanan (1993): place assimilation represents a compromise between articulatory and perceptual demands governing speech production in general. This assumption is based on Lindblom (1988, 1990):

(34) Speech production is the result of reconciling two conflicting demands (ease of articulation and ease of perception, i.e. maintenance of contrasts)

In other words, place assimilation may be viewed as the result of reconciling constraints guided by these two conflicting demands. Constraints motivated by ease of articulation, which we call Weakening constraints, formulate the minimization of articulatory effort. Weakening constraints have the effect of reducing or eliminating consonantal gestures, and this may lead to place assimilation in consonant clusters. (See Chapter Three for the claim that gestural reduction is mainly responsible for the loss of the target gesture in casual speech place assimilation.) These articulatorily based constraints may be outranked by perceptually based constraints motivated by ease of perception. (The type of ease-of-perception constraints employed in the present study we call Preservation constraints.) These Preservation constraints are a type of faithfulness constraints which deal with discrepancies between base and surface forms. As shown in (31b), Prince and Smolensky (1993) originally propose that the Parse requires all underlying segments to be syllabified; if not, they will delete due to 'Stray Erasure'. As mentioned by Prince and Smolensky (1993:25 footnote 12), this original use of Parse can be extended to the constraint which "militates against any kind of failure of underlying material to be structurally analyzed ('loss')..." Flemming (forthcoming) adopts this extended definition of Parse, and he further claims that Parse must be evaluated at the perceptual level. This notion of Parse embodies "the claim that the input and the output must be perceptually similar." The use of Flemming's Parse allows us to substitute a sound with an articulatorily different, but perceptually similar, sound. If the two sounds are perceptually identical, even if articulatorily distinct, there is no Parse violation. Following Flemming's idea about Parse but, employing a different name (leaving Parse for the faithfulness constraints which are evaluated on articulatory properties), we assume that Preservation constraints must be evaluated on perceptual properties. To the extent that the output is not sufficiently similar to the input in terms of its perceptual properties, Preservation constraints are violated. These constraints have the indirect effect of preserving gestures which encode perceptual properties; thus gestural reduction or elimination is blocked and consequently, place assimilation does not occur.

In conclusion, the occurrence and absence of place assimilation in a certain language depends on the interaction between Weakening and Preservation constraints: roughly speaking, if the former outranks the latter, place assimilation occurs; otherwise, no assimilation. As we see in Chapter Four, there are diverse ways of ranking the two conflicting constraints; these different rankings characterize language-specific patterns of place assimilation.

Kirchner (1994) provides an analysis for consonant lenition processes by employing the same type of Optimality-theoretic approach in which main constraints are based on the two conflicting demands in speech production, 'minimization of articulatory effort' and 'maximization of contrast'.

How then can we capture the crosslingustic generalizations and implicational statements which place assimilation typology displays? We claim that such restricted crosslinguistic patterns of place assimilation are the result of applying the universal ranking for Preservation constraints which follows from a hypothesis suggested by Steriade (1993b) and Byrd (1994):

(35) Production Hypothesis[3]

Speakers make more effort to preserve the articulation of speech sounds with powerful acoustic cues, whereas they relax in the articulation of sounds with weak cues.

According to the Production Hypothesis, speakers are reluctant to exert effort on segments which present inherent acoustic weaknesses, since their preservation would not be very helpful for their perception; but speakers are willing to exert effort on an acoustically salient segment since the effort will pay off in enhancing the perceptibility of the segment. In other words, speakers make more effort for those sounds which will produce dividends in terms of enhanced perceptibility. Byrd (1994) adopts the hypothesis (35) to explain the observed difference in overlap

[3]As pointed out by Pat Keating among others, the Production Hypothesis (35) sounds counter-intuitive, since we might think that effort should go where it is most needed. In other words, acoustically weak segments need more effort from speakers in order to be fully contrastive. However, we think this is true when we consider only one of the two demands involved in speech production (34), i.e. ease of perception (more specifically, maximization of contrastive information).

Let us suppose an ideal situation where the same amount of effort is exerted on all types of segments. We may further suppose that with such a default effort, acoustically strong segments are fully contrastive, but acoustically weak ones are less (or non) contrastive. Here, if we consider an ease-of-perception demand, we would exert more effort on acoustically weak segments so that all segments involved can be fully contrastive.

However, the other demand in speech production, i.e. ease of articulation, must be in operation as well. We would then try to save effort in speech production, instead of exerting an extra effort. With what segments should we save effort? Here, the ease-of-perception demand is considered. Acoustically weak segments are already not very contrastive. If we try to save effort with acoustically strong segments, then contrastive information in both acoustically strong and weak segments will be lost. Thus, the second best choice for the ease-of-perception demand is to save effort with acoustically weak segments. They are not very distinctive, anyway. In sum, if we simultaneously consider the two demands in speech production (34), the Production Hypothesis is the natural consequence.

duration between **dg** and **gd**: **dg** is more overlapped than **gd**. She (p.70) assumes that unreleased **d** is acoustically very weak, based on the following discussion (see section 4.2.1.2 for more detailed discussion of this assumption):

> The formant transitions for **d** show relatively small excursions (Öhman, 1967), don't have a large effect on F3, and have an articulation, and hence, formant movement, that is relatively rapid (Kuehn and Moll, 1976).

This acoustic weakness of unreleased **d** leads to little motivation for preserving its articulation, since the preservation of **d**, i.e. slight, or no, overlapping of **dg**, would not result in much better perception of **d**. The same explanation can be adopted for another result of Byrd, namely that **d** of **dg** is more reduced than **g** of **gd**. Because **d** is an acoustically weak segment, there is less motivation to exert articulatory effort in its production.

In fact, Kohler (1990, 1991, 1992) presents the same idea in (35) in explaining segmental reduction processes (including place assimilation) in German, which can be seen in the following series of possible reductions in the German sequence *mit dem*, arranged from most to least careful speech:

(36) (from Kohler 1991 p.187)

I. mɪtʰde:m
mɪtʰdem
mɪtʰdəm
mɪtdm

II. mɪt͡p:m
mɪp:m

III. mɪpm
mɪb̥m
mɪbm
mɪmm
mɪm

This series includes many segmental changes (e.g. vowel quality change, vowel elision, consonant assimilation, consonant deletion and nasalization). To explain this type of segmental reduction processes, Kohler (1991:189) suggests that the role of listeners must be considered as one factor involved in the reduction in connected speech. More specifically, he claims that "reduction processes are favoured that show a low degree of perceptual salience," to explain "why apical fricatives, released apical plosives and syllable- or word-initial nasals and plosives are not assimilated [in German connected speech]." His account is outlined in the following statement (p.189):

(37) Fricatives have more distinctive acoustic structures separating the different places of articulation than nasals and stops, and among the latter, unreleased ones are still less salient than released or even aspirated ones. Furthermore, the syllable- or word-initial position has a higher signalling value for a listener and must therefore be given a more precise articulation by a speaker....What is not very distinctive for a listener anyway may be reduced by a speaker more easily to yield to the principle of economy of effort

As can be suggested by the above statement from Kohler, the Production Hypothesis can capture the acoustic correlation observed in crosslinguistic generalizations of place assimilation: i.e. acoustically weak segments are more likely targets than acoustically strong segments. According to (35), consonants which have inherently weak acoustic cues are more likely subject to weakening processes (i.e. total or partial reduction). Under the assumption that reduction is responsible for the loss of the target in place assimilation (see Ch. 3), the acoustically weak consonants are therefore more likely targets of place assimilation. In contrast, acoustically strong consonants tend to be preserved; thus, they are less likely targets, resisting the reduction. The hypothesis (35) provides a general strategy for ranking Preservation constraints:

(38) <u>Constraints preserving acoustically more salient segments must be ranked above those preserving acoustically less salient segments</u>.

Consequently, Preservation constraints--which can be classified into several sets on the basis of criteria such as place, manner, and prosodic domain--have a universal ranking within each set. For instance, constraints preserving place cues for stops are always ranked above those preserving place cues for nasals; and constraints preserving place cues for onsets are always ranked above those preserving place cues for codas:

(39) Example universal rankings

a. Preserve_place cues_of (stop) >> Preserve_place cues_of (nasal)

b. Preserve_place cues_of (onset) >> Preserve_place cues_of (coda)

(More formalized and elaborated version will be presented in section 4.2.1.)

Consequently, such universal rankings indirectly explain why nasals and codas are more likely targets than stops and onsets respectively.

In summary, attested patterns of place assimilation are the result of reconciling conflicts between articulatorily-based Weakening and perceptually-based Preservation constraints ranked in terms of the Production Hypothesis. The details of the proposal just outlined are in Chapter Four.

In Chapter Two, we describe a brief typological survey of place assimilation. The survey provides crosslinguistic generalizations on place assimilation and their implicational statements. In Chapter Three, we describe oral pressure experiments which have been carried out to determine the articulatory and perceptual mechanisms involved in place assimilation. There we explore English and Korean labial-velar clusters to investigate the distinct roles of gestural reduction and gestural overlap in casual-speech place assimilation. Based on the results of the experiments and the survey, we attempt to provide an Optimality-based theory of speech production in Chapter Four. This theory will indirectly capture place assimilation. Analyses of some attested cases are demonstrated.

Chapter 2

Place Assimilation Typology

In this chapter, we explore place assimilation typology to determine crosslinguistic generalizations and hierarchical implications of place assimilation. Based on the discussion of place assimilation patterns attested in English, Korean, Hindi and Malayalam, Mohanan (1993) claims that attested patterns of place assimilation display variability in targets, triggers, and domains; but, on the other hand, they obey the following crosslinguistic generalizations:

(1) Asymmetries in Place Assimilation (Mohanan p.76 #21)

a. Coronal Asymmetry

(i) If noncoronals undergo assimilation, so do coronals.

(ii) If coronals trigger assimilation, so do noncoronals.

b. Labial-velar Asymmetry

If labials trigger assimilation, so do velars.

c. Stop Asymmetry

(i) Nonstops do not undergo (the whole range of) assimilation.

(ii) If nonstops trigger assimilation, so do stops.

d. Sonorant Asymmetry

(i) If nonsonorants undergo assimilation, so do sonorants.

(ii) If sonorants trigger assimilation, so do nonsonorants.

We will first briefly survey generalizations. We will then discuss these generalizations classified by the manner, place and syllable position of the target and trigger consonants involved in place assimilation. Sections following the description of the survey are organized in the following order: target manner, target place, target position, trigger manner, and trigger place.

2.1 SURVEY

We provide an in-depth discussion of place assimilation patterns attested in the following languages, alphabetically ordered: Brussels Flemish, Catalan, Diola Fogny, English, German, Hindi, Japanese, Keley-I, Korean, Lithuanian, Malay (Thai), Malayalam, Nchufie (Chiyao, Kikuyu), Toba Batak, Yakut, Yoruba, Zoque.[1] In addition, patterns from some other languages (Inuktitut dialects, Kambata, Musey and Russian), will be considered either when we discuss the derived generalizations, or when we attempt to formalize the generalizations in Chapter Four. The main reason why these languages were chosen is that the patterns attested in those languages were relatively well-studied and so have been employed in the previous literature. We investigated the following aspects of each language: (a) possible targets, (b) impossible targets, (c) possible triggers and (d) impossible triggers. In some cases, however, possible targets or triggers could not be determined or we did not have sufficient material to decide the behavior of some consonant classes; in the following description, these two cases are labeled (e) and (f) respectively.

<u>Brussels Flemish</u>

Our discussion of Brussels Flemish is solely based on De Vriendt and Goyvaerts (1989). In Brussels Flemish, /n/ assimilates in place of articulation to a following plosive:

(2) (Vriendt and Goyvaerts p. 54)

a.	[nə<u>mb</u>oːʀ]	een boer	'a farmer'
b.	[ɣiː<u>ŋk</u>ysəs]	geen kussens	'no cushions'

[1]Patterns from parenthesized languages are discussed with those of the language preceding them.

If /n/ occurs before fricatives, liquids and glides, it deletes while its preceding vowel gets nasalized:

(3) (Vriendt and Goyvaerts p.54)

a. Fricatives

(i)	[ə̃vʀa:]	een vrouw	'a woman'
(ii)	[ɣ̃i:ɣustə]	geen goesting	'no inclination'

b. Liquids

(i)	[ə̃li:ʀ]	een ladder	'a ladder'

c. Glides

(i)	[tẽ:ju:ʀ]	tien jaar	'ten years'

If /n/ occurs before a nasal, it deletes but its preceding vowel does not get nasalized:

(4) (Vriendt and Goyvaerts p.55)

a.	/da#kan#ni/	-->	[dakani]	dat kan niet	'this can't be the case'
b.	/ik#vin#niks/	-->	[ikfiniks]	Ik vind niets	'I don't find anything'

Notice that nasal deletion before a nasal applies only to the alveolar nasal:

(5) (from Vriendt and Goyvaerts p.89 footnote 25)

[ikomni] ik kom niet 'I'm not coming'

Processes involving the alveolar nasal which we have discussed so far can be summarized as follows:

(6) Input = ..VnC..

a. if C = stop, then the output = ..VNC.. (NC is a homorganic nasal-stop cluster)

b. if C = nasal, then the output = ..VC..

c. if C = fricative, liquid or glide, then the output = ..Ṽ C..

De Vriendt and Goyvaerts claim that the alveolar nasals assimilate in place to following nasals as well as stops. When nasals are triggers, the derived nasal geminates undergo degemination which is a general process in Brussels Flemish: according to De Vriendt and Goyvaerts (p.15 #6), two identical consonants are always reduced to a single consonant.[2] Following their claim, we assume that nasals can trigger place assimilation. However, we still cannot determine whether fricatives, liquids and glides can trigger the assimilation, since /n/ deletes before them and this nasal deletion cannot be attributed to degemination. A summary of Brussels Flemish place assimilation is given in (7):

(7)

a. Targets: the alveolar nasal (see #2)

b. Non-targets:

<u>Noncoronal nasals (see #5)</u>

<u>Stops</u>

(i) /aə # ze: + t # ə<u>t # p</u>akskə/ --> [aəze:də<u>tp</u>akskə]

hij ziet het pakje ('he sees the small parcel', p.32)

<u>Fricatives</u>

(ii) /kʀɔəz + kə/ --> [kʀoeskə] kruiseje ('cross, dim.', p.11)

c. Trigger: <u>stops (see #5) and nasals (see #4)</u>

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[2] Degemination is fairly common in the phonology of Dutch (Vriendt and Goyvaert p.15).

e. Undetermined

Triggers: fricatives, liquids and glides

f. Unknown
Targets: liquids and glides

The data from De Vriendt and Goyvaerts are not sufficient for us to figure out whether liquids and glides can ever occur in the target position of place assimilation.

Catalan

According to Mascaró (1978), Catalan displays regressive place assimilation where alveolar nasals and stops optionally assimilate to the following consonant (8a). Notice that noncoronals cannot be targeted in the assimilation (8bi,ii).

(8) (all examples chosen from Mascaró, except (aiii) and (biii,iv))[3]

a. Targets:[4]

Alveolar nasals and stops

(i) so[m] pocs 'they are few' (cf. so[n] amics 'they are friends')

(ii) so[ɱ] feliços 'they are happy'

(iii) so[m] wit 'they are eight'

(iv) se[p,] focs 'seven fires' (cf. se[t] 'seven')

(v) se[m] mans 'seven hands'

Liquids

(vi) e[l,][ž]ermá 'the brother'

(vii) e[ł]gos 'the dog'

b. Non-targets:

Noncoronal nasals and stops

(i) so[m] dos 'we are two' (cf. so[m] amics 'we are friends')

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[3]We would like to thank Manuel Español-Echevarria for providing Catalan words (in 8aiii, biii, biv) and their pronunciations for me.

[4]'p,' and ' ł' represent a labiodental stop and a velarized /l/ respectively.

(ii) po[k] pa 'little bread'

Fricatives

(iii) tre[s] pans 'three bread'

Glides

(iv) tre[w] dos 'take off two'

c. Triggers:

Stops (ai), nasals (v), fricative (aii,iv), and glides (aiii)

e. Undetermined

Trigger: liquids

Also, /l/ can assimilate in place to a following palatal or velar (8avi,vii), but it cannot to a following labial: e[l] pa 'the bread'; e[l] foc 'the fire'.[5] Fricatives and glides do not undergo this assimilation (8biii,iv). Regarding triggers, stops, nasals, fricatives, and glides can trigger place assimilation (8c). Because all liquids are alveolar, we cannot determine whether liquids can trigger cross-articulatory assimilation in which only coronals can be targeted.

Diola-Fogny

The following discussion of Diola-Fogny is based on Sapir (1965). In Diola-Fogny, only nasals can form a cluster with the following consonant which could be any of a stop, a nasal and a fricative.

Across morpheme boundaries within the same word, when nasals are followed by a consonant, they behave differently depending on the type of the following consonant. Nasals assimilate in place to following stops and nasals as shown in (9a):

(9) (From Sapir pp.16-17)

a. Targets:

Nasals

(i) ni+gam+gam nigaŋgam 'I judge'

[5] As discussed by Jun (1993:62-63), this must be due to the possible range of laterals. Labial laterals cannot occur, since labial articulations do not involve any part of the tongue.

(ii) pa<u>n+j</u>i+maɲj — paɲjimaɲj — 'you(pl) will know'

(iii) na+ti:<u>ŋ+t</u>i:ŋ — nati:<u>nt</u>i:ŋ — 'he cut (it) through'

(iv) na+mi:<u>n+m</u>i:n — nami:<u>mm</u>i:n — 'he cut (with a knife)'

c. Triggers:

<u>Stops (ai-iii) and nasals (aiv)</u>

e. Undetermined

Targets:

<u>Stops</u>

(i) lɛt+ku+jaw — lɛkujaw — 'they won't go'

(ii) ɛ+rɛnt+rɛnt — ɛrɛrɛnt 'it is light'

(iii) na+manj+manj — namamanj — 'he knows'

<u>Fricatives, liquids and glides</u>

With no relevant examples, Sapir (p.17) provides the following deletion rule:

$(N)C_1 + C_2 > C_2$ (C_2 may be a nasal, C_1 may not.)

Triggers:

<u>Liquids and glides</u>

(iv) na+laɲ+laɲ — nalalaɲ — 'he returned'

(v) na+yɔkɛn+yɔkɛn — nayɔkɛyɔkɛn — 'he tires'

(vi) na+waɲ+a:m+waɲ — nawaɲa:waɲ — 'he cultivated'

f. Unknown

Trigger: <u>fricatives</u>

If a nasal occurs before a liquid or glide, the nasal deletes (9eiv-vi). Across morpheme boundaries, the first consonant of a CC sequence will delete if it is a nonnasal (9ei-iii). Here we cannot determine whether these deleted nonnasals undergo assimilation or not, since they never surface. For the same reason, we do not know whether liquids and glides can trigger assimilation, since nasals are always deleted before them. We also do not have sufficient data to find out whether nasals assimilate to a following fricative.

Let us turn to inter-word morphophonemics which show a slightly different pattern. Nasal assimilation occurs frequently enough but nasals delete before a following nasal:

(10) (From Sapir p.19)

a. Nasals are targets (when stops are triggers)

napum kuɲilak	-->	napuŋkuɲilak	'he pushed back the children'
najum tɔ	-->	najuntɔ	'he stopped there'

b. Nasals delete (when nasals are triggers)

ban ɲa	-->	baɲa	'finish now'

Thus, we cannot determine whether nasals occurring before another nasal undergo assimilation or not.

In summary, in Diola-Fogny, nasals assimilate in place to following stops or nasals across morpheme boundaries within the same word, whereas the trigger status of nasals is not clear in cross-word boundary assimilation.

English

In casual speech, English coronal stops and nasals optionally assimilate to following noncoronal stops, nasals, and fricatives (11a); but noncoronal stops and nasals, fricatives, and liquids are rarely targeted (11b). The relevant examples are shown in (11):

(11)

a. Targets:

Coronal stops and nasals

(i)	'meat ball'	[mi:t bɔl]	≈	[mi:p bɔl]
(ii)	'late kiss'	[leyt kis]	≈	[leyk kis]
(iii)	'man made'	[mæn meyd]	≈	[mæm meyd]
(iv)	'green flower'	[gri:n flawər]	≈	[gri:ɱ flawər]

b. Non-targets:

Noncoronal stops and nasals

(i)	'leap quickly'	[li:p kwikli]	*[li:k kwikli]
(ii)	'pingpong'	[piŋ poŋ]	*[pim poŋ]

Fricatives and liquids

(iii) 'gas pipe'	[gæs payp]	*[gæp payp] or [gæɸ payp]
(iv) 'tool case'	[tul keys]	*[tuk keys] or [tuL keys][6]

c. Triggers:

Stops (ai,ii), nasals (aiii), and fricatives (aiv)

d. Non-trigger:

Glides

(i) 'late work'	[leyt wɔrk]	*[leyp wɔrk]
(ii) 'mean wife'	[mi:n wayf]	*[mi:m wayf]

e. Undetermined

Target: glides

Trigger: liquids

Stops, nasals and fricatives can trigger place assimilation (11c). It cannot be determined whether glides can be targeted or whether liquids can trigger. It seems that in English, glides do not occur before a consonant; in other words, glides never occur in the target position in regressive assimilation. Also, all English liquids are coronal; thus they can never have a chance to trigger cross-articulatory assimilation with the preceding coronal which is the only target place in English place assimilation.

German

German also displays casual speech place assimilation in which only coronals are involved. According to Kohler (1991:186), across syllable boundaries, apical nasals and stops assimilate to the following noncoronal (12a), but noncoronal stops and nasals cannot be targeted (12bi-iii):[7]

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[6]L represents a velar lateral.

[7]In fact, Kohler states that the patterns under consideration are cross-word-boundary phenomena but we think, on the basis of his data, that cross-syllable-boundary is the correct term for the phenomena. Thus, in (12), the word-boundary symbol '#' in Kohler (1990) is replaced by the syllable boundary symbol '.'.

(12) Across syllable boundaries (selected from Kohler 1990 p.86 and p.c.[8])

a. Targets:

Coronal nasals

(i) [n.b] --> [m.b] 'anbringen' ("to attach")

(ii) [n.m] --> [m.m] 'anmelden' ("to register")

(iii) [n.f] --> [ɱ.f] 'anfahren'

Coronal stops

(iv) [t.b] --> [p.b] 'mitbringen' ("to bring along")

(v) [t.m] --> [p.m] 'mitmachen' ("to join")

b. Non-targets:

Non-coronal nasals and stops

(i) [m.k] --> [m.k] 'rumkriegen' ("to win over")

(ii) [k.p] --> [k.p] 'Packpapier' ("wrapping paper")

(iii) [k.m] --> [k.m] 'zurückmelden' ("to report back")

Fricatives, liquids

(iv) [s.g] --> [s.g] 'ausgeben'

(v) [r.g] --> [r.g] 'vorgehen'

Glides (Kohler p.c.)

c. Triggers: stops (ai, iv), nasals (aii, v) and fricatives (aiii)

d. Non-triggers: glides (Kohler p.c.)

e. Undetermined

Triggers: liquids

Kohler (p.c.) informed us that fricatives and liquids cannot be targeted in place assimilation (12biv,v); fricatives can trigger place assimilation but less frequently than stops and nasals (aiii); and glides can be neither triggers nor targets. Also, as discussed with English place assimilation, whether liquids can trigger place assimilation cannot be determined since they cannot trigger cross-articulatory assimilation with a preceding coronal stop or nasal which is the only target place. All these patterns can be observed within a syllable, too. An additional pattern can be observed only within a syllable:

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[8] Many thanks to Klaus Kohler for providing some relevant information about German casual speech place assimilation for us.

(13) Within a syllable (trivially adapted from Kohler 1990 p.85)

a. Additional Target:

Coronal nasals (progressive)

(i) 'Wagen' [va:gən] --> [va:gŋ]

(ii) 'geholfen' [gəhɔlfən] --> [gəhɔlfɱ]

b. Non-target:

Coronal stops (progressive)

'Akt' [akt^{h}] --> *[akk^{h}]

Across syllable boundaries, only regressive place assimilation can occur. In contrast, within a syllable, we also observe progressive assimilation in which only coronal nasals can be targeted (13a) (remember that coronal stops cannot be targeted, as shown in (13b)). Also, notice that if the alveolar nasal is followed by a vowel, this progressive place assimilation may be blocked.

(14) (trivially adapted from Kohler 1990 p.85)

with no following vowel		with a following vowel	
a.	[bən] --> [bm]	b.	[bənə] --> [bnə] or [bm̩nə]
	'eben' ("even")		'ebene' (inflected)
c.	[gən] --> [gŋ]	d.	[gənə] --> [gnə] or [gŋ̍nə]
	'Regen' ("rain")		'gelegene' ("situated", inflected)

Kohler (p.85) states that as shown in (14a,c), the progressive assimilation occurs only when the apical nasal is followed by a consonant or a word boundary after the reduction of *ə*. If the apical nasal is followed by a vowel as in (14b,d), either the nasal stays nonsyllabic and unassimilated, or the nasal becomes syllabic, "leaving apical nasal off-glide to the following vowel." The difference, i.e. absence and presence of progressive assimilation, between cross-syllable-boundary and syllable-internal assimilation can be attributed to presence and absence of the vowel following the alveolar nasal. Syllable-initial nasals can retain place cues in the transition of the following vowel (possibly in the release as well). In contrast, the nasal following a consonant or a syllable boundary is acoustically weak, since it lacks the transition cue in the following vowel. If the nasal release includes its place cue, the word-final nasal would additionally lose this cue under the assumption that the syllable-final nasal is unreleased. Under the Production Hypothesis (Ch 1 #35), acoustically weak segments are more likely to be subject to reduction than acoustically strong segments. From this, it follows that the coronal nasal before a consonant or a syllable boundary can be reduced easily, thus being targeted in place assimilation; but the coronal nasal followed by a vowel is hard to reduce. (See section 4.2.1.3 for more detailed discussion of this issue.)

In summary, in the consonant cluster C_1C_2, if C_1 and C_2 belong to separate syllables, coronal nasals and stops in the C_1 position can be targeted (regressive assimilation); if C_1 and C_2 are tautosyllabic, coronal nasals in the C2 position can additionally be targeted (progressive assimilation).

Hindi

According to Ohala (1975, 1983), morpheme-internally, Hindi nasal consonants must agree in place with a following stop in native words, as shown by the following generalization:

(15) Ohala (1975:323, #15)

In native words, within a morpheme, nasal + stop clusters must be homorganic.

This generalization suggests that in Hindi place assimilation which is displayed within a native morpheme, only nasals can be targeted and only stops can trigger. Relevant examples are chosen from Ohala:

(16) Within a morpheme (all examples in (a) chosen from Ohala 1975 p.327; the rest from Ohala 1983 pp.169-184)

a. Targets:

Nasals

(i) p^həŋki	'handful'	(ii) gend	'ball'
(iii) tamba	'copper'	(iv) gəŋga	'Ganges'
(v) gəɲǰa	'bald'		

b. Non-targets:

Stops

(i) gətka	'a type of club'	(ii) gupta	'a last name'

Fricatives

(iii) sɪski 'sob'

Liquids

(iv) kɪrka	'a small bit of dust'	(v) $\underline{d}^h$olki	'drum'

Glides

(vi) gayki	'style of singing'	(vii) əwd̠er	'confusion'

c. Triggers:

Stops (9a)

d. Non-trigger:

Nasals

(i) samna 'frontage'

Fricatives

(ii) šəmšan 'cremation ground'

Liquids

(iii) ɪmli 'tamarind'

Glides

(iv) kɪnwani 'water droplets'

Also, Mohanan (1993:75) states that Hindi nasal place assimilation can be seen across morpheme boundaries. He provides the data displaying somewhat different patterns with respect to the triggers of place assimilation. The data provided by Mohanan are rearranged in (17).

(17) (Mohanan p.75 #18)

No assimilation

a. aakaar 'shape' samaakaar 'homophonous'

Stop trigger

b. kiirt̪an 'devotional' saŋkiirt̪an 'collective devotional singing'

c. t̪ool 'measure' san̪t̪ool 'equilibrium'

d. calan 'coduct' sancalan 'movement'

Nasal trigger

e. naad̪ 'sound' sannaad̪ 'consonance'

Fricative trigger

f. sriṣṭ 'produced' sansriṣṭ 'joined together'

Liquid trigger

g. reek^{h}aa 'line' sanreek^{h}aa 'alignment'

h. leek^h 'writing' sanleek^h 'protocol'

Glide trigger

i. yog 'meeting' sãỹyog 'chance meeting' (G. Mahajan p.c.)

Unlike morpheme-internal assimilation shown in (16), cross-morpheme boundary one can be triggered by various types of consonants, stops, nasals, fricatives and liquids.[9] Also, G. Mahajan (p.c.) informs me that this assimilation can be triggered by glides as well, providing a relevant example (17i).

In summary, in Hindi place assimilation, only nasals can be targeted both within a morpheme and across morphemes. Regarding triggers of place assimilation, the patterns are different: within a morpheme, only stops can be triggers, whereas across morphemes, not only stops but also other consonants (nasals, fricatives and liquids) can be triggers.

Japanese

It has been known in the literature (e.g. Yip 1991) that heterorganic consonant

[9] Mohanan states that this assimilation "does not occur across words, or even in certain morphological concatenations."

clusters are not allowed in Japanese. Word-finally, only the "mora nasal" (Vance's terminology) can occur: e.g. hoN 'book'.[10] Within a word, only homorganic nasal or geminate clusters can occur.

(18) (Chosen from Kuroda (1979), Vance (1987), and Yip (1991))

a. Homorganic nasal clusters

kampai	'cheers'	sensee	'teacher'
honrai	'originally'	boỹyari	'absent-minded'

b. Geminates

totta	'took'	gakkoo	'school'
simmiri	'guarded'	bassari	'decisively'

From the description of the mora nasal in Kuroda and Vance, its phonetic characteristics are almost the same as those of a following segment (including vowels); i.e. the mora nasal is a copy of the following segment except the nasality. This can be seen in the following statement from Kuroda (p.201):

> The phonetic realization of the nasalized consonantal mora may best be described as a nasalized continuous transition from the preceding segment to the following one.

This may indicate that Japanese homorganic nasal clusters are actually geminates except for the nasality superimposed on their first member. The attested clustering patterns in Japanese, shown in (18), may lead us to the hypothesis that targets and triggers of place assimilation are unrestricted, under the assumption that the gemination patterns are the result of place assimilation which is always accompanied by manner assimilation.

As shown in Kuroda, assimilations, which display surface alternations, can be

[10]See Vance (1987:34-35) for a summary of various arguments about the phonetic description of the mora nasal spoken in isolation.

observed in several areas of Japanese morphology. First, in Sino-Japanese compoundings, if the first morpheme has the form $C_1V_1C_2V_2$, where C_2 is *t* and V_2 is *i* or *u*; and the second morpheme begins with an obstruent such as *k, t, p*, and *s*, then C_2 assimilates to a following morpheme-initial consonant after deletion of V_2:

(19) (From Kuroda p.207)

a.	kotu-kaku	kokkaku	'frame'
b.	situ-pai	sippai	'failure'
c.	ritu-syoo	rissyoo	'proof'

As shown in Chapter One, Cho (1990) has a different interpretation which has been argued by Itô (1986) and Tateishi (1990), and also followed by Padgett (1991): V_2 is an epenthetic vowel when assimilation is blocked. Only coronal stops can be targeted. Also, this assimilation is blocked even with the coronal stop target, when the trigger is voiced, as can be seen in (20).

(20) (From Cho p.57)

a.	it + nen	-->	itinen (*innen)	'one year'
b.	it + bai	-->	itibai (*ipbai, *ibbai, *imbai)	'once'

However, following McCawley (1968), Kuroda (1979) and Vance (1987), we will assume vowel deletion, not vowel epenthesis, for the following reasons. First, it seems that the phonetic quality of V_2 cannot be predicted since /i/ occurs after /t/ in (20a,b) but /u/ occurs after /t/ in the following compound: bet + waku --> betsuwaku 'different category' (Tetsuya Sano, p.c.). Second, Japanese native speakers who we consulted have a somewhat strong intuition that the vowels under consideration are underlying. Finally, the vowel epenthesis proposal in which only coronal stops are targets of place assimilation is not compatible with either Japanese consonant clustering patterns, shown in (18), or place assimilation patterns in Japanese verbal morphology, shown below: coronal stops are not special in either pattern. These reasons might not be sufficient to ensure the vowel deletion proposal, rejecting the vowel epenthesis one. However, we will not pursue this issue in any more detail, since, as can be seen later, neither choice will significantly change either the conclusion of the present chapter or that of the present work.

Let us turn to Japanese verbal morphology. When a verb stem, which ends in *t, n, p, m, r*, or *b*, is followed by a suffix such as *ta*, *te*, *temo*, or *tari*, regressive assimilation occurs:

(21) Chosen from Kuroda p.204 (ta = past tense marker)

	stem	past		
a.	kat	katta	'win'	
b.	sin	sinda	'die'	
c.	kam	kanda	'chew'	
d.	kar	katta	'mow'	
e.	tob	tonda	'fly'	
f.	kaw	katta	'buy'	(from Itô and Mester 1986 p.59)

Several points need to be considered. If the target is a nasal, it retains the nasality (21b,c). If the target is a voiced stop, it becomes a nasal while voicing the trigger (21e). Ito and Mester (p.59 footnote 14) claim that this coda nasalization is "a regular phonological process in Japanese responsible for the surface absence of voiced geminates." More importantly, noncoronals can be targeted (21c,e,f). Also, notice that glides (21f) can be targeted.

In summary, in Japanese place assimilation, there is no restiction to targets and triggers.

Keley-I

According to Hohulin and Kenstowicz (1979), Keley-I displays following patterns of place assimilation:

(22) (From Hohulin and Kenstowicz p.250)

a. Targets: coronal nasal

(i)	tepen	s-im-pen	'measure'	(infix -in-)
(ii)	hemek	h-im-mek	'pity'	

b. Non-targets:

Labial nasal

(i)	teled	ʔum-tetle	'sting'	(prefix and infix (ʔ)um-)
(ii)	kebed	ʔum-kekbed	'scratch'	

Stops, fricatives, liquids and glides (Hohulin and Kenstowicz 1979)

c. Triggers: stops (ai) and nasals (aii)

d. Non-trigger: glides

(i)	tewik	s-in-wik	'prick'	(infix -in-)
(ii)	peyuh	p-in-yuh	'bless'	

e. Undetermined

Target: velar nasal

Trigger: liquids

f. Unknown

Trigger: fricatives

Coronal nasals assimilate in place to a following stop or nasal (22a), but labial nasals do not (22b). Also, coronal nasals do not assimilate to following glides (22d). However, we cannot decide whether fricatives can trigger place assimilation or not, due to lack of the relevant data. Although Hohulin and Kenstowicz do not provide any specific examples which can indicate whether consonants other than nasals can undergo place assimilation or not, they state that the coronal nasal is the only one which shows some alternation; thus, we assume that consonants other than nasals cannot undergo assimilation. Also, in Keley-I, it cannot be determined whether the velar nasal can be targeted, as indicated by the following statement from Hohulin and Kenstowicz (1979:250):

> When standing before a consonant, n assimilates in point of articulation, while m does not. There are no good examples in which the behavior of the velar nasal **ng** can be assessed. It does not unambiguously appear in any prefix or

infix and there are no stems of the shape **ng**eCVC, where, upon deletion of the **e**, the assimilatory nature of ng could be determined.

Again, we cannot decide whether liquids can trigger cross-articulatory place assimilation, since all liquids are coronals.

<u>Korean</u>

In Korean, in casual speech, coronal nasals and stops optionally assimilate in place to following labials and velars (23ai-iii), and in addition, labials assimilate in place to velars (23aiv,v).

(23) Korean place assimilation[11]

a. Targets:

<u>Coronal stops and nasals</u>

(i) /mit+ko/ 'believe' 'and'	-->	[mikko]	'believe and'
(ii) /cinan+pam/ 'last' 'night'	-->	[cinampam]	'last night'
(iii) /san+maɨl/ 'mountain' 'village'	-->	[sammaɨl]	'a mountain village'

<u>Labial stops and nasals</u> (with velar triggers)

(iv) /ip+ko/	-->	[ikko]	'wear and'
(v) /nam + kɨk/ 'south' 'end'	-->	[naŋkɨk]	'the South Pole'

---

[11]Broad phonetic transcriptions are employed for Korean examples. The representations include forms derived by a regular process of Korean coda neutralization in which underlying fortis and aspirated coda consonants are neutralized to their unreleased lenis counterparts in syllable-final position. Also, actual phonetic forms will be outputs of another regular process of Korean post-obstruent fortition in which lenis obstruents become fortis after an obstruent. See Kim-Renaud (1986) for more details about these two regular processes in Korean.

b. Non-targets:

Velar stops and nasals

(i) /ik + ta/ --> [ikta] *[itta] 'ripe + SE'
'ripe' SE[12]

(ii) /paŋ + pota/ --> [paŋpota] *[pampota] '(more) than room'
'room' '(more) than'

Labial stops and nasals (with coronal triggers)

(iii) /ip+ta/ --> [ipta] *[itta] 'wear + SE'

(iv) /sum+ta/ --> [sumta] *[sunta] 'hide + SE'

Liquids

(v) /al+ko/ --> [alko] *[aLko] 'know and'

c. Triggers:

Stops (ai,ii,iv,v) and nasals (aiii)

d. Non-trigger:

Glides

/pap'ɨn+waŋ/ --> [pap'ɨnwaŋ] *[pap'ɨmwaŋ] or [pap'ɨŋwaŋ]
'busy' 'king' 'a busy king'

e. Undetermined

Target: fricatives and glides

Trigger: liquids

However, velars do not assimilate to a following consonant (23bi,ii), and labials do not assimilate to a following coronal (23biii,iv). Also, liquids do not undergo place assimilation (23bv). Stops and nasals can trigger place assimilation (23c) but glides cannot (23d). Finally, it cannot be determined whether fricatives and glides can be targeted, since the only fricative /s/ in Korean is neutralized to its homorganic stop /t/ in the coda position and glides never occur before a consonant in Korean. Also, the liquid /l/ in Korean becomes a nasal after a consonant (e.g. /sam+lyu/ --> [samnyu] 'third class'); thus we cannot decide whether the liquid itself can trigger place assimilation.

[12] SE represents Sentence Ender.

Lithuanian

Kenstowicz (1972) reports a morphophonemic nasal assimilation in Lithuanian, in which the dental nasal /n/ assimilates in place to a following stop or affricate:

(24)

a. Target: dental nasal

(i) sé[m]bernis	'old fellow'	(cf. sẽ[n]as 'old')
(ii) pi[ŋ]kite	'plait, imp. pl.'	(cf. pi[n]a 'plait; 3 pres.')

b. Non-targets: labial nasal

(i) té[m]ti	'darken, infin.' (cf. tẽ[m]o 'darken, 3 past')	
(ii) té[m]kite	'darken, imp. pl.'	

However, when /n/ occurs before nasals, fricatives, liquids and glides, it deletes:

(25) (Formation with a prefix san-: e.g. dora 'virtue' sandora 'covenant')

a. Nasals

moklas 'skill'	sa:mokslas	'conspiracy'

b. Fricative

ʃluoti 'sweep'	sa:ʃlavos	'sweepings'

c. Liquid

lyti 'to rain'	sa:lytis	'clash, contact'

d. Glides

jungas 'yoke'	sa:junga	'union'

Thus, we cannot determine whether consonants other than stops can trigger place assimilation or not, although, as discussed by Kenstowicz, this nasal elision must be related to nasal assimilation, since only dental nasal can be involved in both processes: krimsti '3 past, chew' and krimto 'infinitive, chew' cf. bre:sti '3 past, ripen' and brendo 'infinitive, ripen '. The summary of Lithuanian nasal assimilation is as follows:

(26)

a. Targets: alveolar nasal

b. Nontargets: labial nasal

c. Triggers: stops

e. Undetermined

Triggers: nasals, fricatives, liquids, and glides

Malay

According to Lodge (1992), Malay displays casual speech place assimilation involving all places of articulation. Consonants /p t k m n ŋ/ occurring in coda position can optionally assimilate in place to following stops and nasals:[13]

(27)

a. Targets:

Nasals (trivially adapted from Lodge (1992:42))

(i) [malam tadi] ≈ [malan tadi]

(ii) [malam kames] ≈ [malaŋ kames]

(iii) [makan buah] ≈ [makam buah]

(iv) [hidoŋ mantʃoŋ] ≈ [hidom maṇ̹tʃoŋ]

---

[13] When a nonnasal stop is followed by a nonnasal velar stop, assimilation is blocked:

(i) From Lodge (1992:16)
[bapˀ˺ kəduə] ≈ *[bapˀ˺ kəduə] ≈ [baʔ kəduə] 'the second chapter'

Lodge attributes this blocking to a language-specific constraint which prohibits a nonnasal velar stop in the coda position. Without any further investigation, we simply follow him.

(v) [pasaŋ topeŋ] ≈ [pasan topeŋ]

Stops (Lodge 1992:16)

(vi) [kuatˀ˺ bəladʒa] ≈ [kuapˀ˺ bəladʒa] ≈ [kuaʔ bəladʒa] 'to study hard'

(vii) [hiŋgapˀ˺ di'atas]≈[hiŋgatˀ˺ di'atas] ≈ [hiŋgaʔ di'atas] 'to land on top of'[14]

b. Nontargets: fricatives (s) and liquids (l, r) (Lodge 1992 p.42)

c. Triggers: Stops (ai-iii,v) and nasals (aiv)

e. Undetermined

Targets: glides

f. Unknown

Triggers: glides

Lodge (p.42) states, without providing the relevant examples, that the other possible coda consonants /s l r/ are not involved in assimilation. Thus, we assume that Malay fricatives and liquids cannot be targeted in place assimilation. We also assume that glides cannot occur in the coda position since it is not in the list of possible codas; thus, their behavior in the target position of place assimilation cannot be determined. We finally do not know how fricatives, liquids and glides behave in the trigger position due to insufficient data.

Let us discuss assimilation patterns in more detail. As can be seen in (27avi,vii), stops are obligatorily unreleased and glottalized. Glottal reinforcement is very common in Malay. It may occur before pause (28a,b) and between vowels (28c,d).

(28) (From Lodge 1992 p.15)

a. [hadapˀ˺] 'to face'

b. [dapatˀ˺] 'to obtain'

[14]Lodge adopts ['] for 'the glottal-catch onset to vowel-initial syllables, which is considerably shorter than [ʔ]-realizations of the stops'.

c. [buat^{ʔ} apə] ≈ [buatʔ apə] 'to do what?'

d. [diteop^{ʔ} aŋen] ≈ [diteopʔ aŋen] 'to be blown by the wind'

There are some other languages which display both place assimilation and stop glottalization. As described by Lodge (1986, 1992), Thai displays both patterns. The coda consonants /p t k m n ŋ/ assimilate in place to a following consonant. Stop coda consonants are obligatorily glottalized, as can be seen in the following examples:

(29) (From Lodge 1986 p.338 and Lodge 1992 pp.40-41)

a. /p^{e}u:tmái/ [p^{e}u:t$^{ʔ˺}$mái] ≈ [p^{e}u:p$^{ʔ˺}$mái] ≈ [p^{e}u:mmái][15] 'speak or not'

b. /t^{e}u:kfái/ [t^{e}u:k$^{ʔ˺}$fái] ≈ [t^{e}u:π$^{ʔ˺}$fái] ≈ [t^{e}u:ffái] 'touch the fire'

([π] is a voiceless, labiodental stop.)

Also, in English, as discussed above, coronal stops are often targeted in casual speech place assimilation, and glottal reinforcement accompanied by reduction is common in voiceless stops, especially coronal stop /t/, in coda:

(30) what [wʌt] ~ [wʌt^{ʔ}] ~ [wʌʔ^{t}] ~ [wʌʔ] (Hayes 1992:285)

We are not sure about why glottal reinforcement occurs. We may only conjecture that glottal reinforcement has to do with preservation of voicelessness perception, since it occurs only in voiceless consonants. Although we do not know the exact motivation of glottal reinforcement, it seems true that glottalization plays a role in obscuring the perceptual cue to point-of-articulation of stops (See Lodge 1992 for the relevant discussion). Therefore, according to the Production Hypothesis (Ch. 1 #35), glottalized stops will likely be subject to reduction, leading to place assimilation in consonant clusters. This might explain the difference in place assimilation between English, on the one hand, and Malay and Thai, on the other: in English, coronal stops are more often and more completely glottalized than noncoronals in coda position (Keating p.c.), whereas it seems that both coronals and noncoronals are often/very

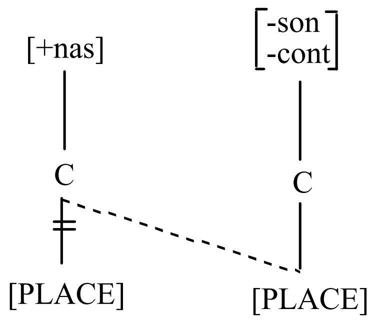
[15]Simple deletion of the target, i.e. [p^{e}u:mái] and [t^{e}u:fái], is also possible.

glottalized in Malay and Thai. However, glottalization is not the main factor explaining the observed asymmetry among these three languages, since nasals, which do not get glottalized, pattern with their corresponding voiceless stops in all the above-mentioned languages (in Malay and Thai, both noncoronal and coronal nasals can be targeted, whereas only the coronal nasal can be targeted in English). Further, glottalization should not be adopted to explain the coronal-noncoronal asymmetry in English place assimilation: the voiced coronal stop /d/ and the coronal nasal /n/ are also asymmetric targets. Without any further investigation, we leave this issue for the future research.

Malayalam

In Malayalam, only nasals assimilate in place to a following stop as indicated in the following rule proposed by Mohanan and Mohanan (1984:583):

(31) Homorganic Nasal Assimilation



According to Mohanan and Mohanan, this rule applies both across word boundaries (32av-viii) and within words (examples in #32 except av-viii):

(32)[16]

a. Targets:

<u>Nasals</u> (with stop triggers; Mohanan and Mohanan #15,16)

(i) [sam [giitam]] --> saŋgiitam 'music' (giitam 'song')

(ii) [[kuḷam][t̲ooṇṭi]] --> kuḷan̲t̲ooṇṭi 'tool to scrape the bottom of the ponds' (kuḷam 'pond'; tooṇṭi 'scraping tool')

(iii) [[peṇ][kuṭṭi]] --> peŋkuṭṭi 'girl' (peṇṇə 'female'; kuṭṭi 'child')

(iv) [[miin][can̲t̲a]] --> miin̄can̲t̲a 'fish market' (miin 'fish'; can̲t̲a 'market')

(v) [awan] [t̲anne] --> awan̲t̲anne 'he himself'

(vi) [baalan][kar̄an̄n̄u] --> baalaŋkar̄an̄n̄u 'the boy cries'

(vii) [baalan] [pooyi] --> baalampooyi 'the boy went'

(viii) [paṇam][t̲ar̄u] --> paṇan̲t̲ar̄u 'give (me) money'

b. Non-targets:

<u>Stops, liquids and fricatives</u> (from Mohanan 1989 p.605)

(i) t̲ikt̲am 'bitter' (from Mohanan and Mohanan p.587)

(ii) spastam 'evident' (from Mohanan 1989 p.619)

(iii) maargam 'way' (from Mohanan 1989 p.622)

c. Triggers: <u>stops (a)</u>

d. Non-trigger: (from Mohanan and Mohanan p.593 #34)

<u>Nasals</u>

(i) n̲anma 'goodness'

(ii) uṇma 'essence'

(iii) suṣumna 'spinal cord'

<u>Fricatives</u>

(iv) himsa 'killing'

<u>Liquids</u>

(v) amḷam 'acid'

f. Unknown

Target: <u>glides</u>

Trigger: <u>glides</u>

[16] Transcriptions adopted by Mohanan and Mohanan are the following: dentals = t̲, n̲; palatalized = r̄, s̄; palato-alveolars = n̄; and retroflexes = ṭ, ṣ, ḷ.

Notice that nasals assimilate in place to a following stop (32a) but not to following nasals, liquids and fricatives (32d). Stops, liquids and fricatives do not undergo this place assimilation (32b). Finally, we do not know glides' behavior with respect to place assimilation.

Nchufie

In Nchufie, a Bantu language spoken in Cameroon, basically no consonant clusters are allowed.[17] Whenever nasals occur before other consonants within words or across morpheme boundaries, they are homorganic. The following data show assimilation of an Nchufie nasal prefix where the nasal assimilates in place to a following stem-initial consonant, lengthening its preceding vowel:

(33)

a. Targets: nasals

(i) /a+ N + tuŋ/	-->	[a:ntuŋ]	'he kicked'
	(a = 3rd person pronoun, N = past tense marker)		
(ii) /a + N + pə:/	-->	[a:mbə:]	'he broke'
(iii) /a + N + ka/	-->	[a:ŋka]	'he ran'
(iv) /a + N + niɲi/	-->	[a:niɲi]	'he cooked'
(v) /a + N + fa:/	-->	[a:ɱfa:]	'he worked'
(vi) /a + N + ɣwe/	-->	[a:ŋgwe]	'he laughed'
(vii) /a + N + liɛ/	-->	[a:ndiɛ]	'he slept'
(viii) /a + N + yiɛ/	-->	[a:njiɛ]	'he said'

[17]Nchufie is also called Bafanji. Most examples are chosen from Jun (forthcoming) which is based on the data elicited in the field methods class at UCLA from 1991 Fall through 1992 Winter. Irrelevant aspects, e.g. tone, are ignored here. For work of varous topics on Nchufie, see UCLA Occasional Papers in Linguistics Volume 14 (Koopman and Kural eds.).

(ix) /a + N + pə + ŋɔ + N + wu + N + wu/ --> [a:mbə ŋɔ ŋgu ŋgu]

he pst be man pst short pst short 'he was a short man'

c. Triggers

Stops (ai-iii), nasals (aiv), fricatives (av,vi), liquids (avii), glides (aviii,ix)

e. Undetermined

Targets: consonants other than nasals

As can be seen in (33), assimilation outputs display different characteristics depending on the type of the trigger consonant. When coronal and velar stops are a trigger, simple place assimilation results (33ai,iii), but when a voiceless labial stop triggers assimilation, it becomes voiced (33aii). When a nasal triggers assimilation, it undergoes degemination (33aiv). If fricative /ɣ/, liquid /l/ and glides /y, w/ trigger assimilation, they undergo post-nasal hardening, becoming their homorganic stops or affricates (33avi-ix). This post-nasal hardening is very common in Bantu languages as can also be seen in the following examples from Chiyao and Kikuyu:

(34)

a. Chiyao (Mtenje 1990, 1991)

Stop trigger

(i) n - pel - ile --> mbesile 'I am tired'
SM Root TM[18]

(ii) n - kat - ile --> ŋgatile 'I have cut'
SM Root TM

Post-nasal hardening

(iii) n - lapit - e --> ndapite 'I have licked'
SM Root TM

(iv) a - n - wugul - ile --> ambugulile 'You open for me'
you(pl)-me-open-for

[18]The abbreviations have the following denotations: SM = subject marker, TM = tense marker.

b. Kikuyu (Clements 1985:244)

	imperative	1st sg. imperfect	stem (gloss)
<u>Stop trigger</u>			
(i)	tɛm-a	n-dɛm-ɛɛtɛ	'cut'
(ii)	kom-a	ŋ-gɔm-ɛɛtɛ	'sleep'
<u>Post-nasal hardening</u>			
(iii)	βur-a	m-bur-eetɛ	'lop off'
(iv)	ɣor-a	ŋ-gor-eetɛ	'buy'
(v)	reh-a	n-deh-eetɛ	'pay'

Here, it is not obvious whether fricatives and nonnasal sonorants can trigger assimilation, since the nasal may undergo assimilation after post-nasal hardening; then this will be a case of stop trigger. However, in Nchufie, at least some fricatives, f and s, trigger assimilation, while not subject to post-nasal hardening. Also, there is a lexical exception to post-nasal hardening: /a + N + li/ --> [a:nli] 'he flew'. Notice that the nasal in the output is still homorganic to the following /l/, although /l/ does not get hardened. Therefore, we will assume that all kinds of consonants can trigger nasal assimilation in Nchufie (probably, Chiyao and Kikuyu as well).

<u>Toba Batak</u>

Hayes (1986) provides an in-depth discussion of optional consonant sandhi phenomena in Toba Batak, while proposing an autosegmental analysis. According to his data, nine consonants can occur before a consonant: voiceless stops (p, t, k), a fricative (s), nasals (m, n, N), and liquids (r, l). Among these, only a coronal nasal undergoes assimilation to a following consonant within words and across word boundaries. As shown in (35a), a coronal nasal totally assimilates to a following consonant; they also lose nasality.

(35) (From Hayes pp.480-490)

a. Targets:

Coronal Nasals

(i) maŋan baoa an (cf. maŋan in isolation)
[b b]
eat man that 'that man is eating'

(ii) soŋon gottina
[g g]
as replacement 'in exchange'

b. Non-targets:

Noncoronal Nasals

(i) manaŋ pulpen
[k p]
or pen 'or a pen'

(ii) maŋinum tuak
[p t]
drink palm wine 'drink palm wine'

(iii) ŋb, mg, ŋm, mŋ are attested (see Hayes p.479 Table 1.)

Stops

(iv) pitpit ≈ piʔpit 'with closed eyes'

(v) mɛtmɛt ≈ mɛʔmɛt 'small'

Fricatives (sp, sk clusters cannot be altered; see Hayes p.479 Table 1.)

Liquids (rp, rk, lp, lk clusters cannot be altered; see Hayes p.479 Table 1.)

c. Triggers:

Stops (ai,ii), and Nasals (nm --> mm, nŋ --> ŋŋ; see Hayes p.479 Table 1.)

d. Non-triggers:

e. Undetermined:

Triggers:

Liquids (l, r) and fricatives (s)

In contrast, if labial and velar nasals occur before a consonant, either they lose nasality before a voicelss consonant (35bi,ii) or they are not altered at all before a voiced consonant (35biii). According to the table summarizing Toba Batak consonant sandhi in Hayes (p.479, Table 1), a fricative and liquids do not undergo assimilation. If stops occur before a consonant, they optionally become a glottal stop (35biv,v), resisting place assimilation. Also, there are only coronal liquids and fricative in Toba Batak; thus, we cannot determine whether they undergo cross-articulatory assimilation to a preceding coronal nasal.[19] Finally, according to the phoneme inventory (Hayes, p.478 #14), glides do not occur in Toba Batak.

Yakut

According to Krueger (1962), in Yakut, verbal and nominal stem-final coronals assimilate in place to following suffix-initial noncoronal stops. In providing the relevant data, following Dobrovolsky (1983), we basically assume that the underlying representation of the suffix-initial segments is the form which appears after stem-final vowels.

(36) Chosen from Krueger (1962:58-99)[20]

a. Targets:

Coronal stops and nasals

(i)	sot-	'to wipe, clean'	sop-popun	'we do not clean'
(ii)	at	'horse'	ak-ka	'to a horse (at + ka)'
(iii)	ün-	'to creep, crawl'	üŋ-kür	'sloping, aslant'
(iv)	aan	'door'	aam-mit	'our door (aan + bit)'

---

[19]Although /h/ appears in the phoneme inventory (Hayes p.478 #14), Hayes states that its phonemic status is not clear: morpheme-finally, it is an allophone of /k/ in a pre-vowel position. When it occurs after a coronal nasal, it becomes [k] triggering an assimilation:

(i) maNan halak i
[k k]
eating person the 'the person is eating'

To avoid this bizarre case, Hayes suggests two alternatives. The first is that the correct phonemic representation is /kalak/ for /halak/ 'person'. The other option is a 'patch-up rule' which takes /h/ to /k/ after /n/. In either option, /h/ does not occur in the trigger position of assimilation: at the point of assimilation, it has been changed to /k/.

[20]The following conventions are employed. Depending on the stem-final vowel, A can be any of a, e, o and ö, and I can be any of i, ü.

b. Non-targets:

Noncoronal stops and nasals

(i)	-tAAɣAr	'comparative case'	sep-teeɣer	'than a tool'
			olom-nooɣor	'than a ford'
(ii)	-kA	'dative case'	sep-ke	'tool'
			ilim-ŋe	'net'
(iii)	-tA	'partitive case'	tobuk-ta	'knee'
			χatiŋ-na	'birch'
(iv)	-bIt'our'		tünnük-püt	'our window'
			tiiŋ-mit	'our squirrel'

Fricatives and liquids

(v)	-kA	'dative case'	χos-ko	'room'
(vi)	-bIt	'our'	kilaas-pit	'our clasroom'
(vii)	-kA	'dative case'	učuutal-ga	'teacher'
			doɣor-go	'friend'

Glides

(viii)	-kA	'dative case'	sirey-ga	'son, boy'

c. Triggers: Stops (ai-iv)

e. Undetermined

Trigger: Nasals, fricatives, liquids and glides

Noncoronal stops, fricatives, liquids and glides do not undergo this place assimilation (36b). Regarding triggers of the place assimilation, only stops clearly trigger assimilation. According to Dobrovolsky (1983:78), suffix-initial segments in Yakut are t, -l, -n, -b, -c, and -k.[21] Thus, noncoronal nasals, fricatives and glides do not occur in the trigger position; thus we cannot determine whether they can trigger place assimilation or not.[22] Again, all liquids are coronal; thus they cannot trigger place assimilation to a coronal stop or nasal.

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[21]*-p* is replaced with *-b* by us.

[22]Some suffixes begin with the velar fricative only when they follow a low vowel; elsewhere it is shown as a velar stop (e.g. aɣa-ɣit 'your school' cf. iskaap-kit 'your cabit').

Yoruba

In Yoruba, as described by Ward (1952), a nasal consonant, which is syllabic before another consonant, assimilates in place to a following consonant:

(37) All examples chosen from Clements (1992:186) except aviii,ix from Ward p.21

a. Targets:

Nasals

(i) m-bɛ	'be well'
(ii) n-dɛ	'be setting a trap for'
(iii) ŋ-ka	'be reading'
(iv) ŋm-kpa	'be killing'
(v) n-se	'be cooking'
(vi) n-lɔ	'be going'
(vii) n-ra	'be buying'
(viii) n-yo	no gloss
(ix) ŋ-wa	no gloss

c. Triggers:

Stops (ai-iv), fricative (av), liquids (avi, vii), and glides (aviii, ix)

Nasals (Clements 1992 p.186)

According to Clements (p.186) citing Ward, "before the glides /w, y, h/, the nasal is realized as syllabic [ŋ]: ŋyɔ, ŋwa, ŋhɔ (with no glosses). Some speakers also use [ŋ] before liquids; ŋlɔ, ŋri." Thus, this indicates that glides do not undergo assimilation and liquids do so on a speaker-variable basis. However, Ward (p.21) states that some speakers tend to produce [ŋ] before l and r, only when they are "articulated somewhat far back on the roof of the mouth." Also, he provides the data displaying assimilated glides (37aviii, ix). Thus, following Ward, we assume that in Yoruba, a nasal consonant assimilates in place to a following consonant, regardless of the manner-of-articulation of the following consonant.

Concerning the question of whether nonnasal consonants can be targeted in place assimilation, as indicated by Ward's (p.25) statement on syllable structure, only a nasal consonant can precede another consonant; thus, it seems that nonnasal consonants are simply irrelevant to the target.

Zoque

Wonderly (1951) shows that in Zoque, heterorganic consonant clusters including nasal-plus-oral ones are attested within words as well as across words. But there is a nasal morphophoneme which assimilates in place to a following stop. We assume it is underlyingly an alveolar nasal /n/, since it surfaces as [n] when it fails to undergo assimilation, as shown in (38d):

(38)

a. Targets:

Alveolar nasal

(i) /n + pama/ --> [mbama] 'my clothing' (n = 'my')

(ii) /n + kayu/ --> [ŋgayu] 'my horse'

b. Nontargets: irrelevant

c. Triggers:

Stops (a) and nasals (see 40a)

d. Nontriggers

glides

(i) /n + waka/ --> [nwaka] 'my basket'

(ii) /n + yomo/ --> [nyomo] 'my wife'

e. Undetermined

Triggers: fricatives and liquids

When the alveolar nasal precedes nasals, fricatives and liquids, the alveolar nasal deletes:

(39)

a.	Nasals	/n + mok/	-->	[mok]	'mok'
b.	Fricatives	/n+faha/	-->	[faha]	'my belt'
c.	Liquids	/n + lawus/	-->	[lawus]	'my nail'

Due to this deletion, it cannot be determined whether nasals, fricatives and liquids can trigger assimilation. However, it seems plausible if we assume that at least nasals can trigger assimilation before undergoing degemination which is a general process in Zoque. Wonderly (p.119) reports morphophonemic alternations in which geminates of non-alveolar consonants p, k, ʔ, h, y are reduced to one consonant: e.g. /nihp + pa/ --> [nihpa] 'he plants it'. Also, according to Wonderly's tables showing attested consonant clusters, geminate consonants are very rare: word-medially, tt is the only stop geminate and nn is the only nasal geminate. Notice that the degemination-after-place assimilation cannot be assumed with fricative or liquid triggers. Thus, we assume that nasals trigger place assimilation just like stops do, but nasals simply delete before fricatives and liquids.

2.2 TARGET

Based on the brief survey, just presented, we now consider what kind of generalizations and implicational statements can be made about the target of place assimilation.

2.2.1 TARGET MANNER

Let us summarize surveyed patterns of place assimilation with respect to the manner of the target in the following table:

(40) (O = 'targeted', X = 'untargeted', blank = 'undetermined' or 'unknown')

	fricative	stop	nasal	liquid	glide
Brussels Flemish	X	X	O		
Catalan	X	O	O	O	X
Diola Fogny			O		
English	X	O	O	X	
German	X	O	O	X	X
Hindi	X	X	O	X	X
Japanese	O	O	O	O	O
Keley-I	X	X	O	X	X
Korean		O	O	X	
Lithuanian			O		
Malay	X	O	O	X	
Malayalam	X	X	O	X	
Nchufie			O		
Toba Batak	X	X	O	X	
Yakut	X	O	O	X	X
Yoruba			O		
Zoque			O		

O indicates that a consonant produced with the corresponding manner of articulation can be targeted in place assimilation, whereas X indicates that it cannot. Undetermined (and unknown) cases are unmarked. For instance, in Korean no fricatives can occur in the target position of place assimilation (i.e. coda); thus, it is impossible to determine whether fricatives can be targeted or not.

From the above short list of attested cases, several observations can be made. First, nonnasal sonorants, i.e. liquids and glides, are rarely involved in place assimilation. Second, among obstruents, fricatives are very reluctant to be involved in place assimilation. Notice that whenever fricatives, liquids or glides can be targeted, so can noncontinuants, stops and nasals (Catalan and Japanese). In addition, among noncontinuants, nasals are more likely to undergo place assimilation than stops. It has been noted in the literature that nasals are the most common target in place assimilation. Unlike languages such as English, in which both nasal and oral stops can be targets of place assimilation, some languages allow only nasal stops to be targeted: Brussels Flemish, Hindi, Keley-I, Malayalam and Toba Batak. Thus, there are languages in which only the nasals are targets of place assimilation, but there are no languages in which only stops can be targeted. The implicational statement emerging here is that if stops are targets of place assimilation, so are nasals. Consequently, we can provide the following implicational statements about target manner:

(41) Target manner

a. If fricatives or nonnasal sonorants are targets of place assimilation, so are stops.

b. If stops are targets of place assimilation, so are nasals.

2.2.2 Target Place

Let us consider place of articulation of the target in place assimilation. The following table shows the surveyed patterns, summarized according to the point-of-articulation of the target:

(42) (O = 'targeted', X = 'untargeted', blank = 'undetermined')

	coronal	labial	velar
Brussels Flemish	O	X	
Catalan	O	X	X
Diola Fogny	O	O	O
English	O	X	X
German	O	X	X
Hindi	O	O	
Japanese	O	O	O
Keley-I	O	X	
Korean	O	O	X
Lithuanian	O	X	
Malay	O	O	O
Malayalam	O	O	
Nchufie	O	O	O
Toba Batak	O	X	X
Yakut	O	X	X
Yoruba	O	O	O
Zoque	O		

This table follows the same conventions adopted in (40). O indicates that a consonant produced at the corresponding point of articulation can be involved as a target, whereas X indicates that it is not. A blank indicates that it cannot be determined whether O or X in the language in question is; the relevant consonants do not occur either in the underlying level or in the target position.

The above table clearly shows that consonants produced at different places of articulation tend to be targeted in place assimilation to a different degree. First, coronals are common targets; all relevant cases in (42) involve coronals as a target. This is a well-known fact. It has been reported and discussed in the literature that crosslinguistically, coronals are favorite targets of place assimilation (Bailey 1970, Kiparsky 1985; Cho 1990; and most work in Paradis and Prunet 1991 among others). In (42), Brussels Flemish, Catalan, English, German, Keley-I, Lithuanian, Toba Batak and Yakut display patterns of assimilation in which only coronals can be targeted.

These languages contrast with languages such as Diola Fogny, Hindi, Korean and Malayalam in which not only coronals but also noncoronals can be targeted. Therefore, there are languages in which only coronals are targets of place assimilation but there are no languages where only noncoronals are targets. This implies that if noncoronals are targets of place assimilation, so are coronals.

Among noncoronals, only the Korean pattern in (42) is relevant in determining whether labials or velars are a more likely target in place assimilation than the other. Korean place assimilation is the only case which shows a discrepancy between labials and velars; in all the other cases involving labials as a target, velars are undetermined. In Korean place assimilation, not only coronals but also labials can be targets, but velars cannot be targeted. This fact somewhat weakly implies that labials are more likely to undergo place assimilation than velars. If the Korean place assimilation facts really reflect on the universal pattern of place assimilation, we can have the following tentative implicational statements:

(43) Target place

a. If velars are targets of place assimilation, so are labials.

b. If labials are targets of place assimilation, so are coronals.

These tentative implicational statements can be supported by assimilation patterns attested in Inuktitut dialects. Dorais (1986) provides a trans-dialectal survey of Inuktitut. According to her survey, any consonant can be the second constituent of a cluster in all dialects; the first constituent can be limited mainly due to regressive (place or manner) assimilation. The degree of restriction is different depending on the dialects. The following table (chosen from Dorais Fig. 2) shows the attested types of consonant clusters of four dialect groups.[23]

---

[23]Dorais's Fig 2 includes nine groups; the remaining groups display either all three types of heterorganic clusters, i.e. alv C, bil C and vel C (1,2,3), or none of them (8,9).

Uvular C clusters occur in the first seven groups (1-7); in Group 7, uvular C clusters are the only heterorganic ones. In Group 8, uvular C clusters tend to become pharyngealized geminates of the second consonant. Group 9 shows a stage of complete assimilation; the number of geminates is greatly increased. Also, a uvular consonant cannot occur in the syllable-final position; thus, even clusters whose second member is a uvular have been changed to velar-initial clusters (RR --> xx, qq --> kX).

(44) (Irrelevant parts, e.g. one concerning uvular C, are ignored.)

4 CO CA	5 AI PE	6 NB KI SE	7 TA IT
vel C bil C alv C	vel C bil C alv/alv	vel C bil/bil alv/alv	vel/vel bil/bil alv/alv

(The abbreviations adopted by Dorais are the following: CO = Copper, CA = Caribou, AI = Chesterfield Inlet Aivilik, PE = Polar Eskimo, NB = North Baffin-Aivilik, KI = South West Baffin Kinngarmiut, SE = Southeast Baffin, TA = Northern Arctic Quebec Tarramiut, and IT = East Coast of Hudson Bay Itivimiut.)

In CO and CA (Group 4), no place assimilation occurs; thus, various types of heterorganic clusters are attested. In AI and PE (Group 5), alveolars have been assimilated in place to the following consonant; thus there remains no heterorganic cluster beginning with alveolars. In NB, KI, and SE (Group 6), labials as well as alveolars have undergone place assimilation; as a result, only heterorganic clusters beginning with velars remain. Finally, in TA and IT (Group 7), even velars have been assimilated regressively; thus no heterorganic clusters remain. Although the attested patterns of consonant clusters in (44) are the results of historical place assimilation, this clearly supports the implicational statements in (43).

2.2.3 Syllable Positions

It has been noted in the literature (Webb 1982, Ohala 1990 among others) that targets and triggers in place assimilation correlate with syllable positions. Syllable onsets are more likely triggers than codas, whereas codas are more likely targets than onsets. In the following schematic representation (Webb 1982:318), a coda C_1 usually assimilates to an onset C_2:

(45) ...V C_1 $ C_2 V...

This asymmetry in place assimilation between onsets and codas has been attributed to their different 'strength' with respect to weakening processes (Webb 1982 citing Vennemann 1972, Hooper 1976, among others): weakening processes occur more often in syllable-final position than in syllable-initial position. (We analyze this 'strength' of a consonant in terms of its inherent acoustic salience in Chapter Four.) The weakness of the coda in place assimilation can be confirmed by the surveyed patterns described in this chapter: all the patterns involve the coda as a target; none of them involve the onset as a target.

This coda weakness in place assimilation automatically leads to another well-known crosslinguistic generalization: regressive assimilation is much more common than progressive assimilation. In Webb's survey in which two hundred languages were surveyed in the Stanford Archiving Project, there is only one exception, i.e. Kambata, an Ethiopian language, where progressive place assimilation occurs in the environment of (45):

(46) Hudson (1980:105)

a.	ub-tooʔi	-->	ubbooʔi	'she fell'
b.	t'uf-tooʔi	-->	t'uffooʔi	'she closed'
c.	dag-tonti	-->	daggonti	'you (sg.) knew'

Musey, discussed by Shryock (1993), is similar exception to the generalization that onsets are more likely triggers as well as less likely targets than codas: Musey displays progressive assimilation in the same environment.

(47) From Shryock pp.3-4

a. feminine enclitic /da/

(i) /hap + da/	[happa]	'gruel + fem'
(ii) /gof + da/	[goffa]	'recent past + fem'
(iii) /kolom + da/	[kolomba]	'mouse + fem'
(iv) /tok + da/	[tokka]	'meeting + fem'
(v) /goŋ + da/	[goŋga]	'slave + fem'

b. masculine gender enclitic /na/

(i) /hap + na/	[hapma]	'white + masc'
(ii) /kuluf + na/	[kuluffã]	'fish + masc'
(iii) /sem + na/	[semma]	'foot + masc'
(iv) /suluk + na/	[sulukŋa]	'vengeance + masc'
(v) /zoŋ + na/	[zoŋŋa]	'young man + masc'

However, in both Kambata and Musey, only suffix-initial (or enclitic-initial) consonants can be targeted. Suffixes (and clitics) are usually prosodically weaker than stems, which may be explained by Silverman's (1995) claim that suffixes do not require much contrastive information, compared to stems. Then, suffix or clitic-initial onsets may be acoustically weaker than stem-final codas in those languages, since lexical retrieval of stems is much harder for listeners than function words. If so, according to the Production Hypothesis (Ch. 1 #35), suffix-initial onsets of those languages will be more likely to be subject to the weakening processes than their stem-final codas, being targeted in place assimilation.[24] Therefore, although onsets are, in general, stronger than codas, suffix-initial onsets may be weaker than stem-

[24] In both languages, both flaps and coronal stops may be targets. We do not know whether this is accidental (perhaps a coincidence of coronals' frequent occurrence as a suffix-initial consonant) or not.

final codas, being targeted in place assimilation.

There is another typical case of progressive assimilation. If we turn to tautosyllabic consonant clusters, especially in word-final position, as shown in the following schematic representation, the word-final consonant C_2 may assimilate progressively to the preceding consonant C_1:

(48) ...V C_1 C_2 #

The relevant examples can be seen in German casual speech assimilation: e.g. /va:gən/ --> [va:gŋ̩] 'Wagen'. If C_2 is an unreleased stop or nasal, it is acoustically very weak, compared to C_1 which can retain place cues in the preceding vowel transition. Due to this acoustic weakness, C_2 tends to be reduced, being targeted in place assimilation.

Consequently, although regressive assimilation is much more common than progressive assimilation, its occurrence depends on syllable positions and other contextual factors. Let us summarize the generalizations that we have discussed above:

(49)

a. ..V C_1 \$ C_2 V.. C_1 is a target and C_2 is a trigger.

b. Possible exception to (a):

If C_2 is suffix-initial, C_2 may be a target and C_1 may be a trigger.

c. ...V C_1 C_2 # C_2 is a target and C_1 is a trigger.

If we consider only hierarchical relations between syllable positions, putting aside cases involving morphological details (49b) or relation among constituents within a syllable position (49c), we may suggest the following implicational statement[25]:

[25]This does not mean that these two cases (49b,c) are exceptions to our explanatory mechanism which will be presented, in full, in Chapter Four. We put them aside, simply because they are too specific, compared to other cases which we consider to provide universal generalizations on place assimilation. As long as these cases (49b,c) are subject to the Production Hypothesis, they will directly fall out from our mechanism, as can be seen in Chapter Four.

(50) Syllable Position

If the onset is a target of place assimilation, so is the coda.

2.3 TRIGGER

Different types of consonants may behave differently in triggering place assimilation. If C_aC_b --> C_bC_b but C_aC_c --> C_aC_c, then C_b would be considered a more likely trigger of place assimilation than C_c. Let us now consider generalizations and implicational statements about the trigger of place assimilation.

2.3.1 TRIGGER MANNER

The following table shows the summary of the surveyed patterns of place assimilation classified according to the manner of the trigger:

(51)

		fric	stop	nasal	liquid	glide
Brussels Flemish			O	O		
Catalan		O	O	O		O
Diola Fogny	(across morphemes)		O	O		
	(across words)		O			
English		O	O	O		X
German		O	O	O		X
Hindi	(within a morpheme)	X	O	X	X	X
	(across morphemes)	O	O	O	O	O
Japanese		O	O	O	O	O
Keley-I			O	O		X
Korean			O	O		X
Lithuanian			O			
Malay			O	O		
Malayalam		X	O	X	X	
Nchufie		O	O	O	O	O
Toba Batak			O	O		
Yakut			O			
Yoruba		O	O	O	O	O
Zoque			O	O		X

This table follows the same conventions adopted in (40) and (42). O indicates that a consonant produced with the corresponding manner of articulation is involved as a trigger, whereas X indicates that it is not. In cases where it cannot be determined, the cell is left blank.

One observation from (51) is that consonants produced with different manners of articulation have different tendencies in triggering place assimilation. Several more specific observations can follow. First, nonnasal sonorants, liquids and glides rarely trigger place assimilation, although liquids are often undetermined. Second, stops, nasals and fricatives often trigger place assimilation. Among these, stops are the most common trigger: they trigger place assimilation in all surveyed patterns. Whenever nasals or fricatives trigger place assimilation, so do stops. It is not clear which one, a fricative or a nasal, is a more likely trigger in place assimilation, since they pattern together in (51). Consequently, observations from (51) can lead us to the following implicational statements about trigger manner:

(52) Trigger manner

a. If nonnasal sonorants trigger place assimilation, so do nasals and fricatives.

b. If nasals or fricatives trigger place assimilation, so do stops.

2.3.2 TRIGGER PLACE

Most surveyed patterns do not show any asymmetric patterns with respect to the trigger place. The typical asymmetric pattern would involve the following case: C_aC_b --> C_bC_b but C_aC_c --> C_aC_c, where a, b and c are indexes representing different articulators. The only relevant case is from Korean place assimilation. In Korean, labials do not assimilate to the following coronals but they do to the following velars. This pattern indicates that velars are more likely to trigger place assimilation than coronals. Thus, in the absence of counterexamples, we will assume the following statement as one of our implicational statements on place assimilation:

(53) Trigger place

If coronals trigger place assimilation, so do velars.

2.4 CONCLUSION

According to the brief survey in section 2.1, attested patterns display language-specific variability, but they are subject to the implicational statements, summarized below:

(54)

a. <u>Target manner</u>

(i) If fricatives or nonnasal sonorants are targets of place assimilation, so are stops.

(ii) If stops are targets of place assimilation, so are nasals.

b. <u>Target place</u>

(i) If velars are targets of place assimilation, so are labials.

(ii) If labials are targets of place assimilation, so are coronals.

c. Syllable Position

If the onset is a target of place assimilation, so is the coda.

d. Trigger manner

(i) If nonnasal sonorants trigger place assimilation, so do nasals and fricatives.

(ii) If nasals or fricatives trigger place assimilation, so do stops.

e. Trigger place

If coronals are triggers, so are velars.

It seems that the implicational statements in (54) basically support but somewhat elaborate on Mohanan's generalizations (1), repeated below:

(1) Asymmetries in Place Assimilation (Mohanan p.76 #21)

a. Coronal Asymmetry

(i) If noncoronals undergo assimilation, so do coronals.

(ii) If coronals trigger assimilation, so do noncoronals.

b. Labial-velar Asymmetry

If labials trigger assimilation, so do velars.

c. Stop Asymmetry

(i) Nonstops do not undergo (the whole range of) assimilation.

(ii) If nonstops trigger assimilation, so do stops.

d. Sonorant Asymmetry

(i) If nonsonorants undergo assimilation, so do sonorants.

(ii) If sonorants trigger assimilation, so do nonsonorants.

What are the differences between them? First, in (54), we consider somewhat specific segmental classes, e.g. nasal and nonnasal sonorants, whereas Mohanan considers broad classes, e.g. sonorants. Second, a generalization on syllable positions targeted in assimilation (54c) is not in (1). Third, Mohanan provides two asymmetries among three major points of articulation in triggering assimilation. Mohanan's labial-velar asymmetry (1b) is based on the following statement (p.76):

> Third, there are instances where the velar triggers assimilation and the labial does not (/pk/ --> [kk], but not /kp/ --> [pp]); there are none where the labial triggers assimilation and the velar does not (/kp/ --> [pp], but not /pk/ --> [kk]).

Notice that in the cited patterns, velars and labials are not compared with the same target. If we assume the asymmetries in (54b) among points of articulation for targets (i.e. velars are less likely targets than labials), then the cited patterns follow. The cited patterns do not say anything about the relative strength of velars and labials in triggering assimilation. Thus, as we discussed in section 2.3.2, we can have only the asymmetry between coronals and velars.

After we explore the mechanism of casual speech place assimilation in Chapter Three, in Chapter Four we will consider what phonetic motivation underlie the implicational statements in (54). There we will discuss the correlations between the implicational statements and acoustic facts, some of which have been pointed out by Ohala (1990) and Kohler (1991). We will then provide an explicit formal analysis of the implicational statements by proposing an independently motivated mechanism in which perceptually and articulatorily motivated constraints compete for the optimal output in speech production.

Chapter 3

Oral Pressure Experiments

In this Chapter, we explore the mechanism of casual speech place assimilation; more specifically, we investigate which articulatory process between gestural overlap or gestural reduction is mainly responsible for the perceptual loss of the target gesture in place assimilation.

To investigate the distinct roles of gestural overlap and reduction, I explore pk clusters in Korean and English. It has been assumed in the literature on Korean phonology (Kim-Renaud 1974 and Cho 1990, among others) that in casual speech, coronals assimilate in place to a following non-coronal (1a,b); labials assimilate only to a following velar (1c,d).

(1) Korean Place Assimilation[1]

a.	/mit + ko/	-->	[mikko]	'believe + and'
b.	/cinan + pam/	-->	[cinampam]	'last night'
c.	/nup + ko/	-->	[nukko]	'lie + and'
but				
d.	/nup+ ta/	-->	[nupta]	'lie + Sentence Ender'

This process is optional, and dependent on the style and the rate of speech.

English displays similar alternations in casual speech: coronals assimilate in place to following velar and labial consonants (2a,b). However, English place assimilation is different from Korean place assimilation in that labials rarely assimilate to the following velar consonant (2c).

[1] As in Chapter Two, broad phonetic transcriptions are employed for these Korean examples.

(2) English Place Assimilation

a. red car /red ka:/ [reg ka:]

b. green paint /gri:n peint/ [gri:m peint] (Nolan 1992:262)

but

c. leap quickly /li:p kwikli/ [li:p kwikli], *[li:k kwikli]

Regarding the difference between Korean and English place assimilations (Korean place assimilation is more extensive than the English process), overlap and reduction-based theories make different predictions. An overlap-based theory predicts that in Korean, labial stops should fully overlap with following velars, leading to the perceptual disappearance of the labials; but in English, labials should not overlap with following velars, or overlap only slightly. In contrast, a reduction-based theory predicts that in Korean, labials should often reduce before velars, but in English, labials should rarely reduce in the same environments. In other words, an asymmetry in the reduction process of the labial in labial-velar clusters would explain the difference between Korean and English place assimilations. These two different predictions may be tested if we can measure (i) the degree of gestural overlap in labial-velar clusters, and (ii) the extent of labial reduction in the same clusters.

3.1 METHOD

To examine gestural overlap of pk and gestural reduction of p, I employ the methodology pursued by Silverman and Jun (1994) for an aerodynamic analysis of Korean labial//velar clusters. In that study, oral airflow as well as pharyngeal and oral pressure were recorded in Korean [VCCV] sequences involving both labial and velar consonants, and front and back vowels: [ipki, upku, ipku, upki, ikpu, ukpi, ikpi, ukpu].[2] Recorded pressure changes demonstrate inter-consonantal overlap and reduced articulations.

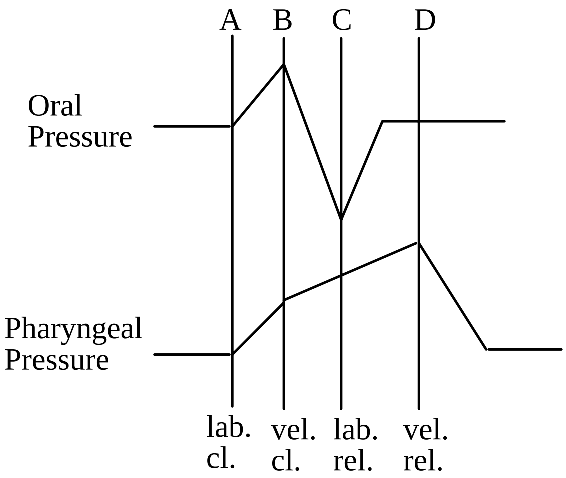
---

[2]Oral pressure refers to the suprapharyngeal pressure, which was recorded behind the lips.

3.1.1 *DETECTING OVERLAPPED ARTICULATIONS*

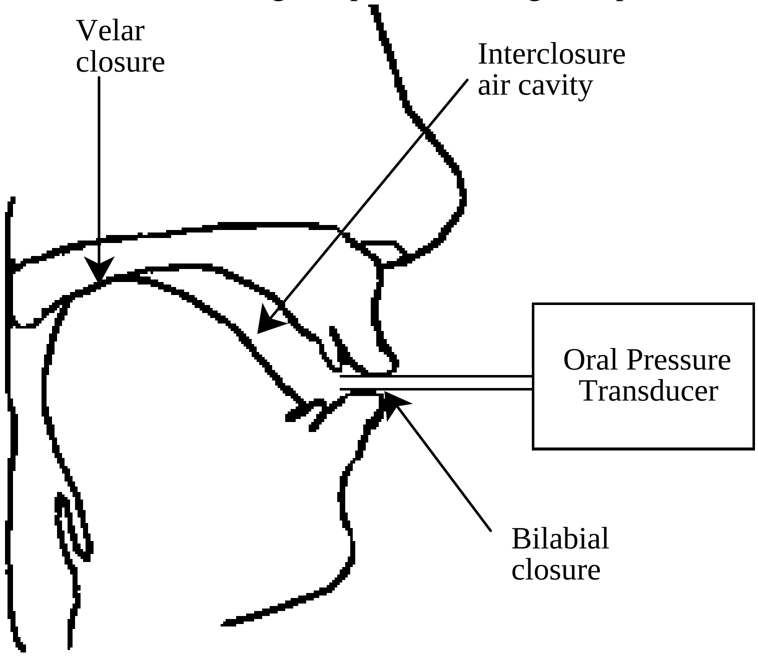
Inter-consonantal overlap is prominent in the following figure, which schematizes the pressure change of labial-velar clusters flanked by front-back vowel combinations, i.e. [ipku]:

Figure 1. Schematic representation of pressure readings for [ipku]



Notice that after the initial increase (Point A), the oral pressure drops below the baseline (Point B). It was claimed by Silverman and Jun that this pressure rarefaction results from a combination of consonant co-production and trans-consonantal vowel coarticulation. While the tongue body moves backward due to the front-to-back vowel transition, simultaneous labial and velar closures for medial pk stops seal the oral cavity at both ends, lips and the soft palate (See Fig. 2).

Figure 2. Method of measuring oral pressure during multiple closures

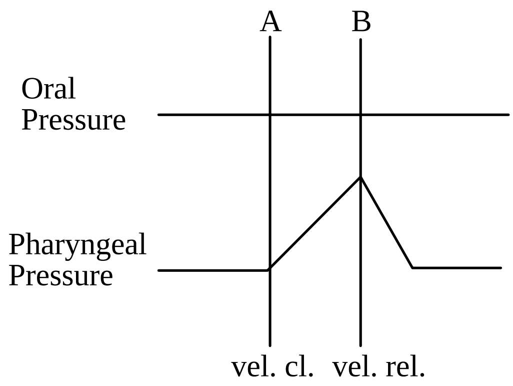


The tongue body backing across the soft palate expands the sealed oral cavity, leading to the negative pressure. (See Silverman and Jun for discussion of the related back-front vowel combinations in conjunction with intervocalic -p//k- sequences, e.g.[upki].) Thus, an observed pressure rarefaction indicates that the labial-velar sequences are highly overlapped.

3.1.2 Detecting Reduced Articulations

A pressure output which indicates labial reduction is schematised in Fig. 3:

Fig 3. Schematic representation for pressure reading of [ipku] with reduced labial



Here, the labial-velar sequence displays no changes in oral pressure. Because the labial closure is not completely achieved, no pressure builds up behind the lips. Thus, no change in pressure indicates that the labial gesture is reduced, completely or partially. (Alternative interpretations of the no-change pressure pattern will be discussed later.) Consequently, Silverman and Jun have demonstrated that both gestural reduction of a labial consonant (Fig. 3) and gestural overlap of a labial-velar cluster (Fig. 1) can be detected in oral pressure changes.

Applying this method, I investigated gestural overlap of labial-velar clusters and gestural reduction of labials in Korean and English. Measuring oral pressure alone, I performed four sets of experiments: production and perception experiments with Korean pk clusters; production and perception experiments with English pk clusters; a production experiment with Korean pt clusters; and production experiments with Korean cross-word boundary pk and prepausal p.

3.2. EXPERIMENT ONE: KOREAN pk

3.2.1 PRODUCTION

Subjects included native Korean speakers of the Seoul dialect (seven females; seven males) living in Southern California. They consider their Korean uninfluenced by foreign languages. Four of them had lived in America one year; one of them two years; two of them three years; four of them four years; two of them five years; one of them eight years. All of them were more comfortable with Korean than English. All the subjects were unaware of the purpose of the experiment.

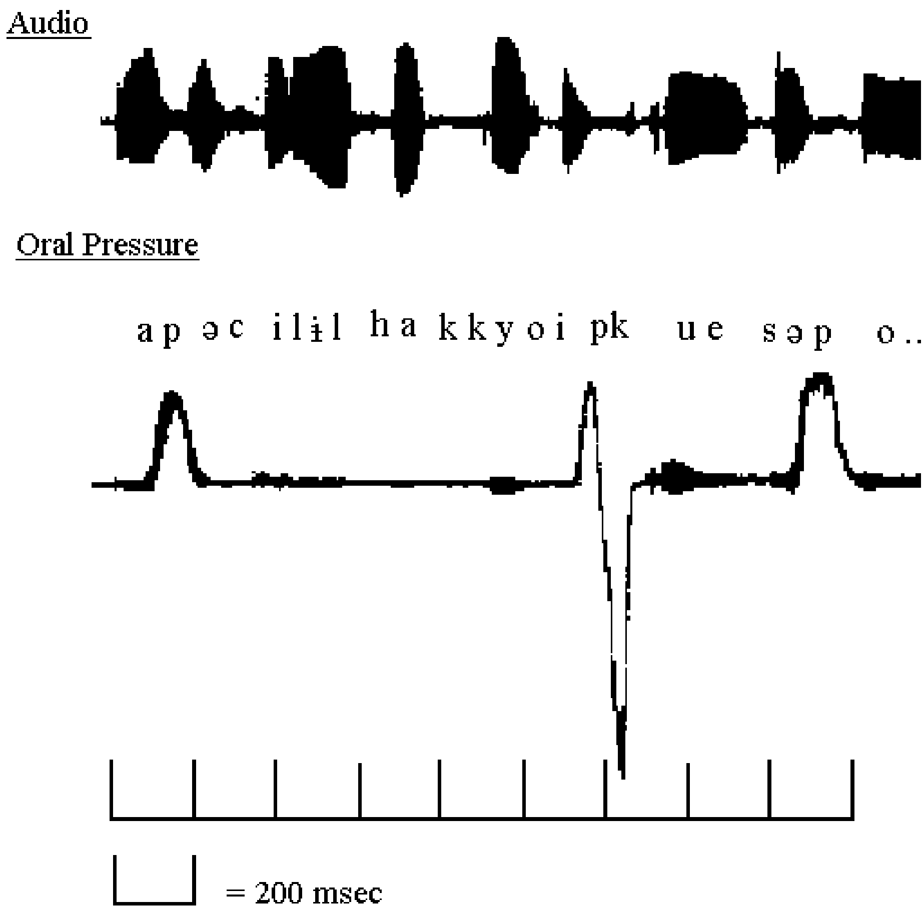
The subjects were fitted with a mouth mask connected to pressure/flow transducers. The pressure tube was inserted behind the lips, thus recording oral pressure (See Fig. 2). Additionally, audio recordings were made. Air flow was not recorded.

For the experimental tokens, V_1pkV_2 sequences were employed; V_1 and V_2 represent front and back vowels, respectively. Real Korean words with these sequences were placed in phrasal/sentential contexts. Appendix I is a complete list of the phrases and sentences employed.

Control tokens (V_1kkV_2), which form a minimal pair with the test tokens (V_1pkV_2) were also recorded (Appendix II). The subjects were instructed to read each phrase in a casual way three times and in a careful, formal way three times, making six times altogether.

Five different patterns of oral pressure resulted. The first pattern (108 out of 330) displays a positive-then-negative change in oral pressure.

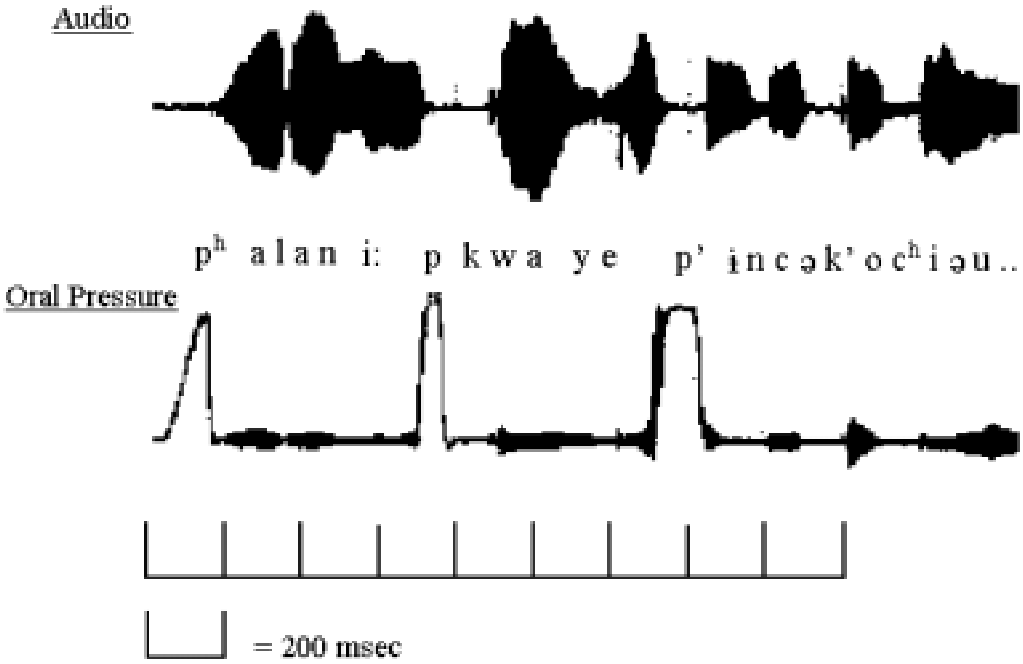
Figure 4. Positive-then-negative --> p^k



In Fig. 4, three changes can be noted in the oral pressure. The change in the middle is for the relevant cluster pk. The other two increases are the labial consonants which precede and follow the relevant pk cluster. As discussed above (section 3.1.1), the observed pressure rarefaction indicates that the medial pk cluster is highly overlapped, although the underlying ordering, i.e. labial-velar, is still maintained: the pressure increase initiated by the labial closure precedes the pressure rarefaction which can occur only after the velar closure. This pattern of oral pressure reading will be designated with the symbol p^k, which is intended to suggest the overlap of the cluster.

Second, 52 out of 330 results displayed a positive-only pressure change, as in Fig. 5.

Figure 5. Positive-only --> p|k



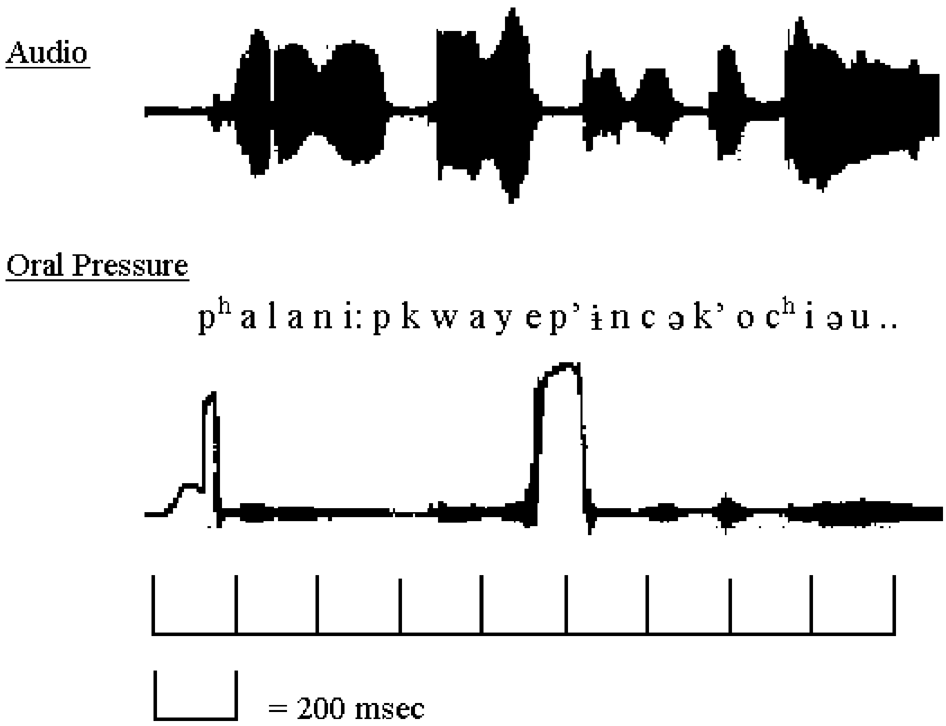
Three increases are noted in oral pressure. The one in the middle is for the relevant cluster pk. Let us provide a plausible interpretation for the observed positive-only pressure pattern. As mentioned above, Silverman and Jun (1994) claim that the pressure rarefaction for V_1pkV_2 tokens, where V_1 is front and V_2 back, would be the result of a marked overlap of the medial pk. From this claim, it follows that the observed positive-only for the medial cluster pk may indicate either a non-overlapped or only slightly overlapped cluster. If closure phases of the pk cluster are not overlapped, velar closure would be made after the labial release. In this case, tongue body backing across the soft palate would occur only after the labial seal is broken, so pressure rarefaction would not result. Oral pressure changes are affected only by the labial closure, leading to a positive-only pressure contour.

If the closure phases of the pk cluster are only a little overlapped, the velar backing in the sealed oral cavity may not last long enough to produce negative pressure; therefore, pressure drops, but not below the baseline.

I consider these two interpretations plausible under the assumption that the tongue body backing due to the front-to-back vowel transition always occur. (See section 3.6.2 for the detailed discussion of this assumption.) However, either possibility involves a less overlapped pk than that represented by pressure rarefaction. Thus, the positive-only pressure pattern will be referred to with the symbol p|k, which suggests inessential overlap of pk.

Third, 156 out of 330 results display no changes in oral pressure.

Figure 6. No-change --> <p>k

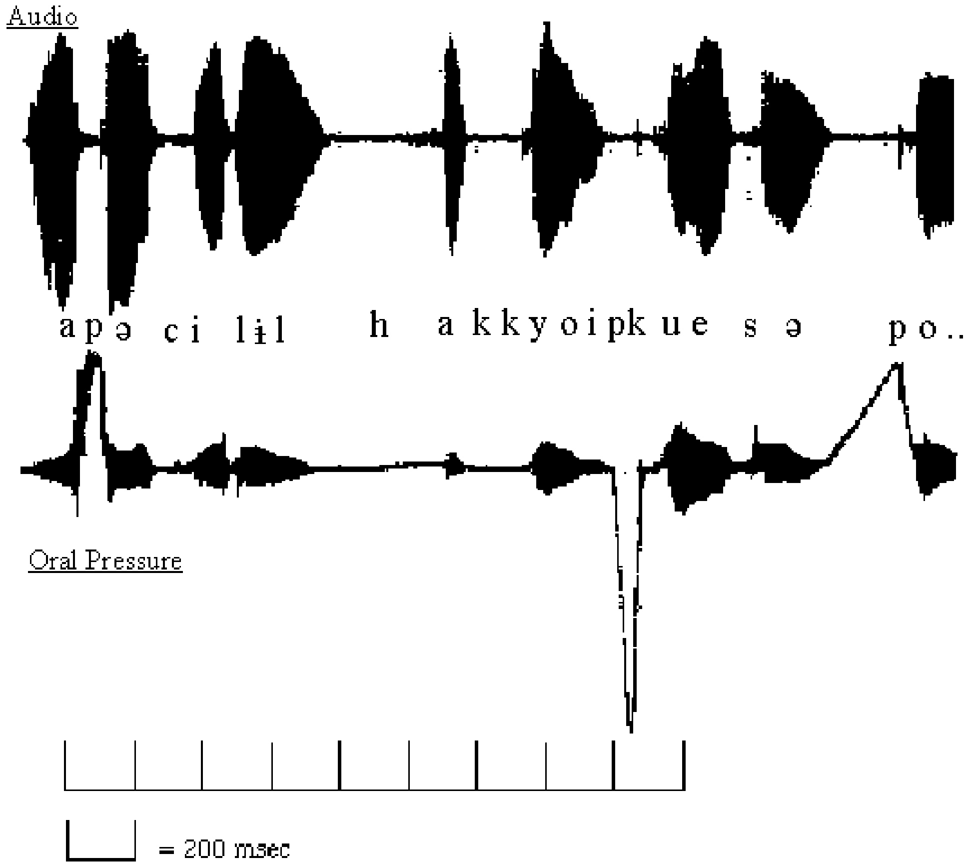


Notice that in oral pressure, there are no changes for the medial cluster pk. The observed increases are for the labials preceding and following the relevant pk cluster. As discussed above (section 3.1.2), no change in pressure implies that the labial gesture of the relevant pk cluster was reduced; i.e. the labial closure which would obstruct the oral air flow was not made completely. This pattern will be called <p>k, a symbol intended to suggest the labial reduction.

There is an alternative interpretation for the observed no-change pressure pattern, based on the possibility of glottalization before oral closure. If glottalization completely blocks air flow at the glottis, no oral pressure change would occur. It has been assumed in the literature on Korean phonology (Kim-Renaud 1986, among others) that Korean coda obstruents are neutralized to their homorganic lenis stops. If this is correct, the labial in the pk cluster would not be glottalized, so it would not block air flow at the glottis. However, Sawashima et al.'s (1980:129) fiberscopic study on Korean coda obstruents reports that Korean coda consonants are glottalized: "the degree of glottal opening for the consonant sequences of the syllable-final applosives followed by the lax and forced [fortis] stops is almost the same as that of the syllable-initial forced [fortis] stop." Nonetheless, that study also shows that the glottis is not completely blocked during coda articulation: "the basic laryngeal feature of the Korean syllable-final applosives is characterized by a small degree of opening, which begins at or slightly after the oral closure." Incomplete blockage allows air flow to escape through the glottis, leading to pressure increase during labial closure. For this reason, I exclude the possibility that the observed lack of change in oral pressure results from glottalization before oral closure. Gestural reduction of the labial is the only plausible interpretation of the no-change pressure pattern.

Fourth, several tokens (13 out of 330) displayed a negative-only pattern in oral pressure.

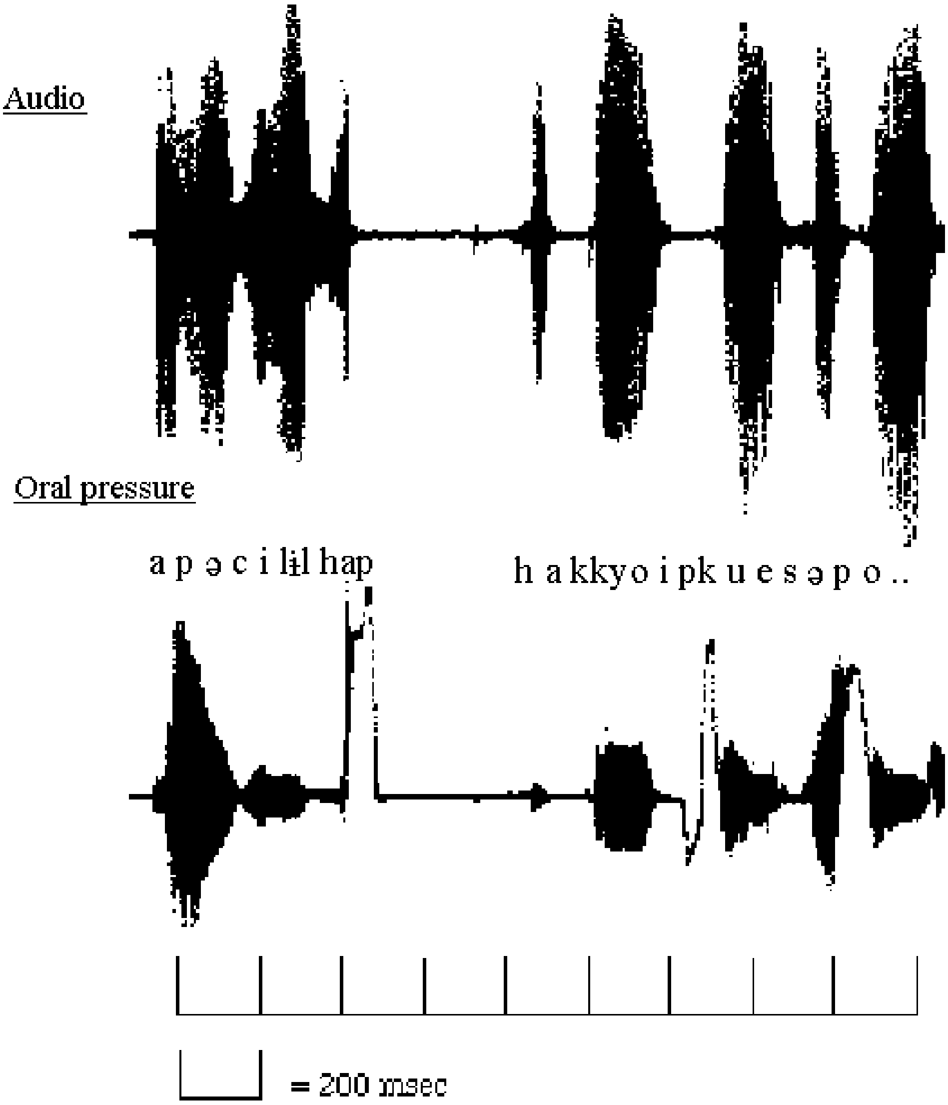
Figure 7. Negative-only --> k^p^k



In figure 7, only pressure rarefaction is observed for the medial cluster pk. This pressure rarefaction, together with the absence of a pressure rise, indicates that the labial closure is surrounded by the dorsal closure. If the dorsal closure is made first despite the underlying ordering of the pk cluster, then the following labial closure would result in the observed direct pressure drop, since the tongue body started retracting across the soft palate even before the labial closure; thus, there is no chance for the pressure to rise at the beginning of labial closure. Next, when the labial closure is released, the pressure returns to the base line. The following velar closure release cannot be seen in the oral pressure reading. Thus, the observed negative-only pressure pattern can result from the labial closure surrounded by the dorsal closure. I consider these pk clusters as cases of extreme overlap, and refer to them with the symbol k^p^k.

Finally, only a single output displayed a negative-then-positive pressure pattern for the medial cluster pk:

Figure 8. Negative-then-positive --> k^p



In figure 8, a negative pressure precedes a positive one. This pressure pattern is typical for velar-labial clusters, not labial-velar. (See Silverman and Jun for discussion of the pressure reading for a velar-labial sequence.) On the audio recording, the cluster sounds like [kp]. Moreover, this output is the only such one out of 330 results. Also, it appears in a phrase in which the subject made a production error: he mistakenly uttered 'hap' for the initial syllable of the experimental phrase 'hakkyo ipku...'. Therefore, this output will be considered a speech error, and will be ignored for the rest of the present study.

Thus far, I have discussed oral pressure patterns observed in results of the Korean pk production experiment. A summary is given in (3).

(3) Summary of relations between oral pressure patterns and interpretations

Label	Oral pressure pattern	Interpretation
p|k	positive-only	slight or no overlap
p^k	positive-then-negative	marked overlap
<p>k	no-change	reduction
k^p^k	negative-only	extreme overlap

Let us now consider a complete set of results produced by each subject, classified by oral pressure pattern and speech style:[3]

[3]No significant differences were observed in the pressure outputs from different experimental phrases.

(4) Results of Korean pk production[4]

<table>
<tr><th>Subject</th><th>Style</th><th>p|k</th><th>p^k</th><th><p>k</th><th>k^p^k</th><th>k^p</th></tr>
<tr><td>m 1</td><td>casual</td><td>0</td><td>0</td><td>12</td><td>0</td><td></td></tr>
<tr><td></td><td>formal</td><td>0</td><td>5</td><td>3</td><td>4</td><td></td></tr>
<tr><td>m 2</td><td>casual</td><td>3</td><td>7</td><td>2</td><td>0</td><td></td></tr>
<tr><td></td><td>formal</td><td>2</td><td>10</td><td>0</td><td>0</td><td></td></tr>
<tr><td>m 3</td><td>casual</td><td>4</td><td>6</td><td>1</td><td>0</td><td>1</td></tr>
<tr><td></td><td>formal</td><td>8</td><td>4</td><td>0</td><td>0</td><td></td></tr>
<tr><td>m 4</td><td>casual</td><td>0</td><td>0</td><td>12</td><td>0</td><td></td></tr>
<tr><td></td><td>formal</td><td>0</td><td>0</td><td>10</td><td>2</td><td></td></tr>
<tr><td>m 5</td><td>casual</td><td>0</td><td>0</td><td>12</td><td>0</td><td></td></tr>
<tr><td></td><td>formal</td><td>0</td><td>3</td><td>8</td><td>1</td><td></td></tr>
<tr><td>m 6</td><td>casual</td><td>6</td><td>0</td><td>6</td><td>0</td><td></td></tr>
<tr><td></td><td>formal</td><td>1</td><td>8</td><td>2</td><td>1</td><td></td></tr>
<tr><td>m 7</td><td>casual</td><td>0</td><td>0</td><td>11</td><td>0</td><td></td></tr>
<tr><td></td><td>formal</td><td>0</td><td>1</td><td>8</td><td>3</td><td></td></tr>
<tr><td>f 1</td><td>casual</td><td>2</td><td>8</td><td>2</td><td>0</td><td></td></tr>
<tr><td></td><td>formal</td><td>1</td><td>9</td><td>1</td><td>1</td><td></td></tr>
<tr><td>f 2</td><td>casual</td><td>3</td><td>6</td><td>3</td><td>0</td><td></td></tr>
<tr><td></td><td>formal</td><td>0</td><td>12</td><td>0</td><td>0</td><td></td></tr>
<tr><td>f 3</td><td>casual</td><td>2</td><td>1</td><td>9</td><td>0</td><td></td></tr>
<tr><td></td><td>formal</td><td>1</td><td>5</td><td>6</td><td>0</td><td></td></tr>
<tr><td>f 4</td><td>casual</td><td>1</td><td>0</td><td>11</td><td>0</td><td></td></tr>
<tr><td></td><td>formal</td><td>3</td><td>9</td><td>0</td><td>0</td><td></td></tr>
<tr><td>f 5</td><td>casual</td><td>6</td><td>0</td><td>5</td><td>1</td><td></td></tr>
<tr><td></td><td>formal</td><td>4</td><td>1</td><td>2</td><td>0</td><td></td></tr>
<tr><td>f 6</td><td>casual</td><td>0</td><td>0</td><td>12</td><td>0</td><td></td></tr>
<tr><td></td><td>formal</td><td>1</td><td>5</td><td>6</td><td>0</td><td></td></tr>
<tr><td>f 7</td><td>casual</td><td>2</td><td>3</td><td>7</td><td>0</td><td></td></tr>
<tr><td></td><td>formal</td><td>2</td><td>5</td><td>5</td><td>0</td><td></td></tr>
<tr><td>Style</td><td>Casual</td><td>29</td><td>31</td><td>105</td><td>1</td><td>1</td></tr>
<tr><td></td><td>Formal</td><td>23</td><td>77</td><td>51</td><td>12</td><td>0</td></tr>
<tr><td>Total</td><td></td><td>52</td><td>108</td><td>156</td><td>13</td><td>1</td></tr>
</table>

Several observations about production of Korean pk clusters can be made.

First, the labial in pk clusters often reduces: 47% of tokens displayed the <p>k pattern in oral pressure.

[4]In the table, m and f represent male and female respectively.

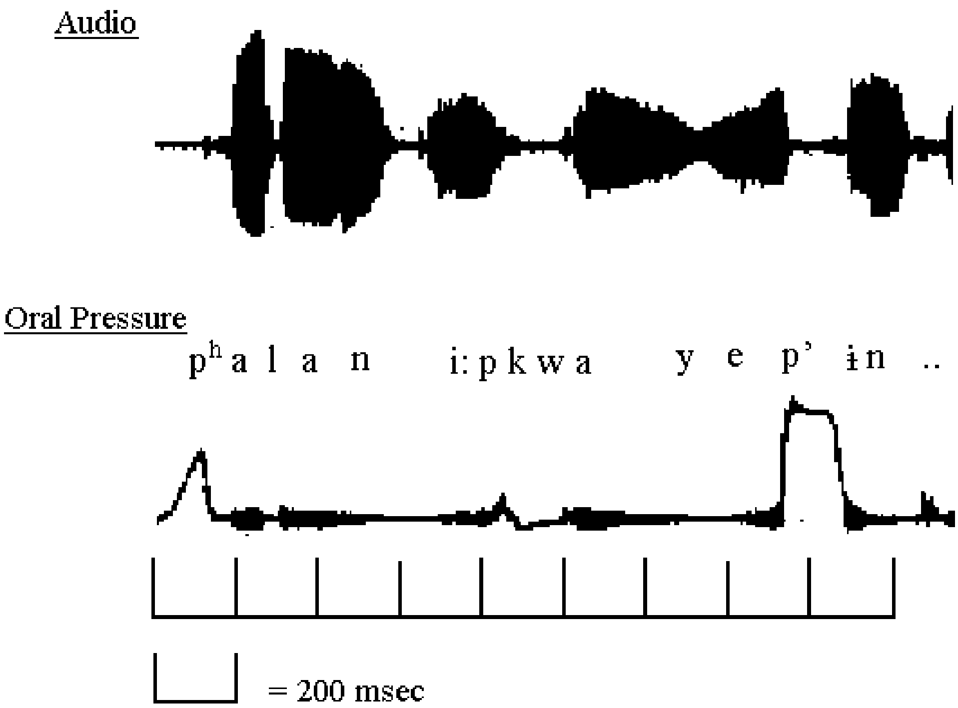
Second, 70% of tokens with unreduced p displayed the p^k pattern; that is, in most unreduced tokens, pk is highly overlapped.

Third, a marked difference between casual speech and formal speech is observed in the frequency of reduced labial (<p>k): in a cluster C_1C_2, when C_1 is p, it reduces more often in casual speech (105/167 tokens) than in formal speech (51/163 tokens).

Fourth, pressure patterns vary across speakers: for instance, speakers m1, m4, m5, m7 and f6 produced <p>k outputs for all the trials in casual speech, whereas speakers m2, m3, f1 and f2 produced p^k outputs for more than half the trials in casual speech.

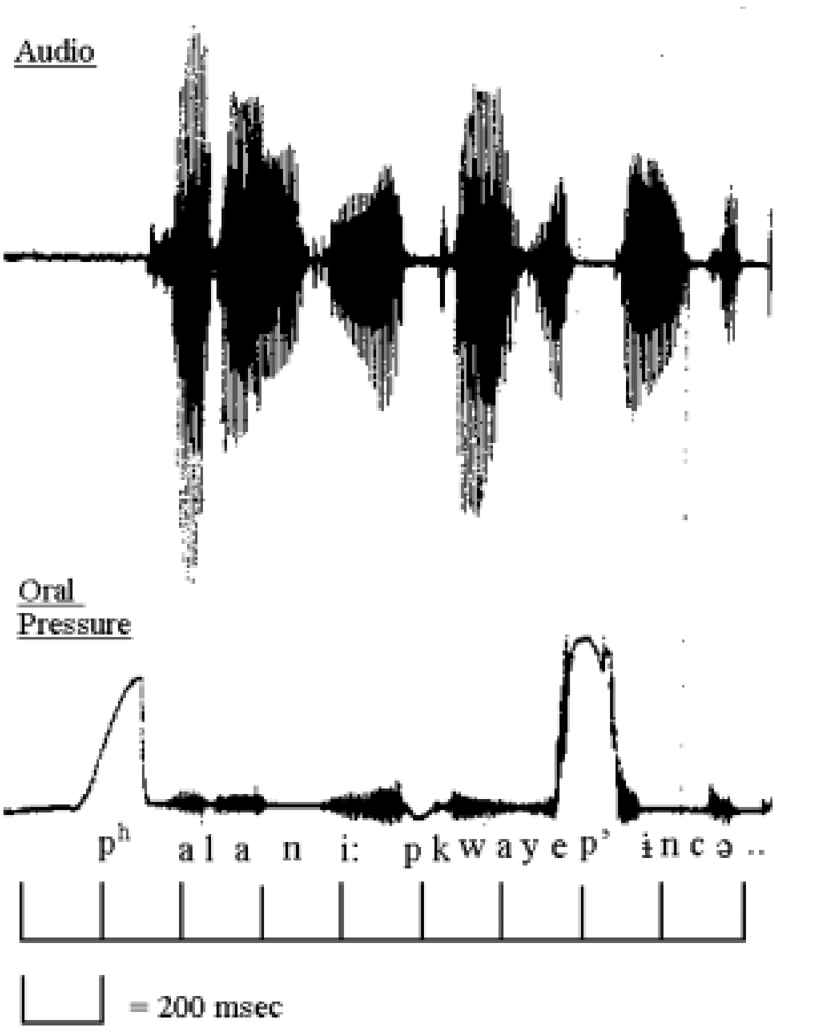
All these observations are classified on the basis of the pressure patterns defined above. An additional observation, which is independent of those canonical pressure patterns, can be made. Some outputs displayed a fairly small change for the relevant pk cluster in oral pressure:

Figure 9. Weak positive-then-negative --> {p}^k



In figure 9, the medial cluster pk displays a positive-then-negative pattern (p^k) in oral pressure. However, the pressure change is very small, compared to the changes for flanking onset labials and the changes which can be seen in the canonical p^k outputs as shown in Figure 4. Equally weak pressure changes can be seen in other types of tokens.

Figure 10. Weak negative-only --> k^{p}^k



In figure 10, the medial cluster pk displays a negative-only pattern (k^p^k) in oral pressure. Again, the pressure change is very small, compared to the changes for flanking onset labials and the changes which can be seen in the canonical k^p^k outputs as shown in Figure 7.

Results displaying very small changes in oral pressure indicate that the labial closure in the pk cluster is barely made; it is incomplete. In other words, the labial gesture is partially reduced, seemingly approximated. (See section 3.6.2 for the discussion of an alternative interpretation for the observed weak pressure changes.) A symbol {} is used to represent partial reduction: e.g. {p}^k.[5] The observed outputs with partially reduced labials imply that at least some, if not all, <p>k tokens result from partial reduction of the labial. Recall that the methodology employed cannot trace articulatory movement of the labial in <p>k type tokens; thus, in general, partial reduction and complete elimination of the labial gesture cannot be distinguished. However, as discussed above, observed weak pressure changes indicate partial reduction of the labial. Thus, we conclude that Korean labial reduction is basically partial, although the reduction could sometimes be maximal.

3.2.2 PERCEPTION

We will now consider the question of which articulatory outcomes result in perceived assimilation, making use of perceptual experiments. Two groups of subjects were employed: six Korean-speaking listeners and six English-speaking listeners. The Korean subjects had never been phonetically trained. The English speaking subjects were phonology/phonetics graduate students at UCLA.

The following segmental sequences were extracted from the audio recordings made in the production tests: various outcomes for V_1pkV_2 and V_1kkV_2 sequences. Listening through headphones to three repetitions (with a one-second inter-stimulus interval) of the same token, subjects were asked to determine whether they heard [V_1pkV_2] or [V_1kkV_2]. Subjects were instructed not to guess; if they could not decide, they were not allowed to respond. Subjects were given a second chance to listen to tokens for which they had not decided on the first hearing.

The following tokens were selected for presentation.

(a) Eight tokens were culled from each of three canonical pressure patterns: p|k, p^k, and <p>k. Four out of the eight tokens were of the sequence ipko and the other four tokens were of ipkwa. Among the four tokens of each type, two were chosen

[5]Notice that each group symbolized with {}, e.g. {p}^k, is a subset of the corresponding group symbolized without {}, e.g. p^k.

from the casual speech sample and the other two from the formal speech sample.[6] Also, control tokens (V_1kkV_2) which can form a minimal pair with chosen underlying pk tokens (V_1pkV_2) were selected.

(b) In addition, three tokens whose oral pressure output belongs to the k^p^k pressure pattern were employed. All of them were of the sequence ipko and from formal speech. These three k^p^k tokens, together with tokens in (a), displayed canonical pressure changes as shown in Figures 4, 5, 6 and 7; none of them displayed small changes in pressure of the type illustrated in Figures 9 and 10.

(c) Finally, two tokens which did display very small changes in oral pressure were employed. One token belongs to {p}^k pattern and the other to the k^{p}^k pattern; their pressure readings are shown in Figures 9 and 10.

The full set of tokens presented is given in the following chart:

(5) Tokens for perception test of Korean pk

<table>
<tr><th rowspan="2">Style</th><th colspan="4">(a)</th><th>(b)</th><th colspan="2">(c)</th></tr>
<tr><th>p|k</th><th>p^k</th><th><p>k</th><th>kk</th><th>k^p^k</th><th>{p}^k</th><th>k^{p}^k</th></tr>
<tr><td rowspan="2">formal</td><td>ipko
ipko</td><td>ipko
ipko</td><td>ipko
ipko</td><td>ikko
ikko</td><td rowspan="2">ipko
ipko
ipko</td><td rowspan="2">ipkwa</td><td rowspan="2">ipkwa</td></tr>
<tr><td>ipkwa
ipkwa</td><td>ipkwa
ipkwa</td><td>ipkwa
ipkwa</td><td>ikkwa
ikkwa</td></tr>
<tr><td rowspan="2">casual</td><td>ipko
ipko</td><td>ipko
ipko</td><td>ipko
ipko</td><td>ikko
ikko</td><td rowspan="2"></td><td rowspan="2"></td><td rowspan="2"></td></tr>
<tr><td>ipkwa
ipkwa</td><td>ipkwa
ipkwa</td><td>ipkwa
ipkwa</td><td>ikkwa
ikkwa</td></tr>
</table>

We first provide results of perception test employing the first group of tokens (p|k, p^k, <p>k) described under (a) above. Results of the perception test for the six Korean speaking subjects are shown in (6). The values in the table indicate the number of tokens identified by the subjects as involving a cluster beginning with a

[6]Recall that in the production test, subjects were instructed to speak in two different speech styles, casual and formal. Thus, the distinction between casual and formal speech in the results of the present experiments may not necessarily have physical correlates.

labial rather than a velar. The total number of tokens in each cell is four, if not otherwise indicated.[7]

(6) Perception of p (Korean pk; Korean subjects)

<table>
<tr><th rowspan="2">Frame</th><th rowspan="2">Subject</th><th colspan="4">number of cases (out of 4) heard as [pk]</th></tr>
<tr><th>p|k</th><th>p^k</th><th><p>k</th><th>kk</th></tr>
<tr><td>i__o</td><td>1</td><td>4</td><td>4</td><td>0</td><td>0</td></tr>
<tr><td></td><td>2</td><td>4</td><td>4</td><td>0</td><td>0</td></tr>
<tr><td></td><td>3</td><td>4</td><td>4</td><td>0</td><td>0 (3)</td></tr>
<tr><td></td><td>4</td><td>4</td><td>4</td><td>0</td><td>0</td></tr>
<tr><td></td><td>5</td><td>4</td><td>4</td><td>0 (3)</td><td>0</td></tr>
<tr><td></td><td>6</td><td>4</td><td>4</td><td>0</td><td>0</td></tr>
<tr><td>i__wa</td><td>1</td><td>4</td><td>4</td><td>1</td><td>0</td></tr>
<tr><td></td><td>2</td><td>4</td><td>4</td><td>0</td><td>0</td></tr>
<tr><td></td><td>3</td><td>4</td><td>3</td><td>0</td><td>0</td></tr>
<tr><td></td><td>4</td><td>4</td><td>3 (3)</td><td>1</td><td>0</td></tr>
<tr><td></td><td>5</td><td>4</td><td>4</td><td>1</td><td>0</td></tr>
<tr><td></td><td>6</td><td>4</td><td>3 (3)</td><td>0 (3)</td><td>0</td></tr>
</table>

[7]Recall that subjects were allowed not to respond, if they could not decide. In these cases, total number of responses is indicated in parentheses.

Style	Subject	number of cases (out of 4) heard as [pk]			
		p|k	p^k	<p>k	kk
casual	1	4	4	1	0
	2	4	4	0	0
	3	4	3	0	0 (3)
	4	4	3 (3)	1	0
	5	4	4	0	0
	6	4	3 (3)	0	0
formal	1	4	4	0	0
	2	4	4	0	0
	3	4	4	0	0
	4	4	4	0	0
	5	4	4	1 (3)	0
	6	4	4	0 (3)	0

The two tables in (6) are different classifications of the same results: the first table is classified by token frame, the second by speech style.

All subjects identified p in all the p|k tokens whose pk clusters, we assume, are not overlapped or are slightly overlapped. The same results can be observed from p^k tokens whose pk clusters are assumed to be highly overlapped, although a little variation can be seen: subject three failed to identify p of one token, and subjects four and six did not respond for one token. Thus, p|k and p^k are not very different in their tendency to induce identification of p.

In contrast, the subjects largely failed to identify p in tokens of <p>k which are assumed to have a reduced labial: three subjects managed to identify p only in one token, and one subject did not respond for one token in the labial identification of control tokens. These results are completely different from the results of tests with p|k and p^k tokens, but very much like results for the control tokens with underlying kk clusters: only one subject did not respond for one token. Consequently, it seems that pk clusters of the type p|k and p^k are perceived as such, whereas /kk/ and <p>k are perceived as [kk].

These observations are confirmed by the perception test using six English speaking (phonetics/phonology student) subjects. Its results are summarized in the following table:

(7) Perception of p (English subjects)

Frame	Subject	number of cases (out of 4) heard as [pk]			
		p|k	p^k	<p>k	kk
i__o	1	4	4	0	0
	2	4	3	0	0
	3	3	3	1	1
	4	4	4	0	0
	5	4	4	1	0
	6	4	3	0	0
i__wa	1	3	4	0	0
	2	4	3	0	0
	3	3	4	0	0
	4	4	4	0	0
	5	4	4	1	0
	6	3	3	0	0

<table>
<tr><th rowspan="2">Style</th><th rowspan="2">Subject</th><th colspan="4">number of cases (out of 4) heard as [pk]</th></tr>
<tr><th>p|k</th><th>p^k</th><th><p>k</th><th>kk</th></tr>
<tr><td>Casual</td><td>1</td><td>4</td><td>4</td><td>0</td><td>0</td></tr>
<tr><td></td><td>2</td><td>4</td><td>3</td><td>0</td><td>0</td></tr>
<tr><td></td><td>3</td><td>4</td><td>4</td><td>0</td><td>0</td></tr>
<tr><td></td><td>4</td><td>4</td><td>4</td><td>0</td><td>0</td></tr>
<tr><td></td><td>5</td><td>4</td><td>4</td><td>2</td><td>0</td></tr>
<tr><td></td><td>6</td><td>3</td><td>3</td><td>0</td><td>0</td></tr>
<tr><td>Formal</td><td>1</td><td>3</td><td>4</td><td>0</td><td>0</td></tr>
<tr><td></td><td>2</td><td>4</td><td>3</td><td>0</td><td>0</td></tr>
<tr><td></td><td>3</td><td>2</td><td>3</td><td>1</td><td>1</td></tr>
<tr><td></td><td>4</td><td>4</td><td>4</td><td>0</td><td>0</td></tr>
<tr><td></td><td>5</td><td>4</td><td>4</td><td>0</td><td>0</td></tr>
<tr><td></td><td>6</td><td>4</td><td>3</td><td>0</td><td>0</td></tr>
</table>

Although somewhat more variation can be noted, the overall pattern is comparable with the results of the perception test employing Korean speaking subjects. Two English-speaking subjects [1, 6] failed to identify p in only one p|k token and one other subject [3] failed in two p|k tokens. Two subjects [2, 6] failed to identify p in two p^k tokens, and one subject [3] failed in one p^k token. These failures are negligible compared to the successes that most subjects achieved in most trials. In contrast, in the labial identification of <p>k tokens, one subject [5] succeeded in two tokens, and another one [3] succeeded in one token. Again, these results are completely different from results with p|k and p^k tokens, but close to the results with the /kk/ control tokens. One subject mistakenly identified p in one control token.

From these results, three important observations follow. First, pk clusters which are highly overlapped (p^k) are still perceived as pk just like those which are not or at most slightly overlapped (p|k). Second, pk clusters whose first labial gesture is reduced (<p>k) are perceived as kk. Thus, the boundary between perceptual assimilation and non-assimilation can be characterized by gestural reduction, not by gestural overlap.

Let us go on to consider the results of k^p^k tokens, whose pressure outputs display negative-only pressure contours. The total number of tokens in each cell, if not indicated, is three. Again, the table's interior shows the number of tokens in which subjects identified the first consonant as a labial.

(8) Perception of p (k^p^k tokens)

Subject	number of cases (out of 3) heard as [pk]	
	Korean	English
1	3	1(2)
2	3	1(2)
3	2	3
4	3	3
5	1	3
6	1 (2)	1

A total of six subjects (three subjects from each subject group) identified the underlying p for all three experimental tokens. The other six subjects identified p in at least one out of two or three tokens. These results indicate that even pk clusters with extreme overlap are not necessarily perceived as kk. In fact, half of the subjects were able to identify p for all three test tokens. We conjecture that although the labial closure phase in these cases is entirely obscured, the labial movements toward and away from closure are subtly discernable from their effects on neighboring formant transitions.

Finally, the results of tokens whose pressure output displays very small pressure changes ({p}^k and k^{p}^k) are shown in (9). The total number of tokens in each cell, if not indicated, is one.

(9) Perception of p (tokens with partially reduced labial)

Subject	number of cases (out of 1) heard as [pk]			
	{p}^k		k^{p}^k	
	Korean	English	Korean	English
1	0	0	0	0
2	0	0	0	0
3	0	1	0	0
4	1	0	0	0
5	0	0	0	0
6	1	0	0 (0)	0

Two Korean speaking subjects [4, 6] and one English speaking subject [3] identified p in the {p}^k token. All the other subjects failed to do so. Thus, it seems that the {p}^k token was heard in general as assimilated. On the other hand, all subjects failed to identify p in the k^{p}^k token except one Korean speaking subject who did not respond for that token. Thus, it seems that the k^{p}^k token with a partially reduced labial was heard as assimilated. If we compare the results of these {p}^k and k^{p}^k tokens to those of their canonical counterparts, p^k and k^p^k, shown in (6-7) and (8), a marked difference can be noticed in the frequency of perceptually assimilated tokens. These results suggest that partial as well as complete reduction of the labial can give rise to perceptual assimilation.

The following table shows a summary of the results reported and discussed thus far.

(10) Summary of perception test with Korean pk

Canonical tokens	p|k	p^k	<p>k	k^p^k
Perceived	pk	pk	kk	pk = kk
Partially reduced tokens		{p}^k		k^{p}^k
Perceived		kk		kk

Shaded areas indicate types of tokens which can be subject to perceptual assimilation most of the time. In conclusion, the observations which follow from the results of the perception test suggest that in Korean labial-velar consonant clusters, labial reduction obscures the perception of the labial, but a marked overlap of the consonant cluster does not in general obscure the perception of the labial unless labial reduction, partial or complete, is involved. In other words, it is gestural reduction, not gestural overlap, that plays the decisive role in the perceptual assimilation of Korean labials.

3.3 Experiment Two: English pk[8]

Let us now consider whether English speakers behave like Korean speakers in the production and perception of labial-velar stop clusters.

3.3.1 Production

American English native speakers (two females; six males), graduate and undergraduate students attending UCLA, were recorded. All of them were unaware of the purpose of the experiment.

The same methods used in the production experiment of Korean pk were adopted. V_1p#kV_2 sequences were employed; V_1 and V_2 represent front and back vowels respectively. Real English words with these sequences were put with a carrier phrase "Say ____ again". (11) is a complete list of the phrases employed.

(11) a. cheap quality b. deep qualm
c. keep quiet d. sleep quickly
e. sheep quota

Control tokens (V_1kkV_2), which form a minimal pair with test tokens in (11) (V_1pkV_2), were also recorded:

(12) a. leek quality b. weak qualm

[8] Experiment Two has benefited from many suggestions by Dan Silverman.

c. seek quiet d. peak quickly

e. teak quota

Each phrase was read by the subjects in a casual way three times.

Results of the production test of English pk are shown in (13).

(13) Results of English pk production

Subject	p|k	p^k	<p>k	k^p^k
f 1	1	14	0	0
f 2	8	7	0	0
m 1	1	14	0	0
m 2	4	10	0	1
m 3	9	6	0	0
m 4	10	5	0	0
m 5	1	14	0	0
m 6	4	11	0	0
Total	38	81	0	1

Several observations can be made from the above results. First, unlike the results in the production experiment for Korean pk, only three different patterns (p|k, p^k, k^p^k) of oral pressure resulted; <p>k outputs characterized aerodynamically by no-change were not attested. The absence of <p>k suggests that labial closure in the articulation of English pk is never reduced.

Second, in the result totals, p^k is the dominant pattern, although there is variation across subjects. Results of p^k (81 occurrences) are twice as common as those of p|k (38 occurrences). And of the rest, only a single token displays the k^p^k pressure pattern. Thus, these results indicate that English pk clusters are mostly highly overlapped.

Consequently, English pk clusters are not very different from Korean pk clusters in gestural overlap, since both clusters are usually highly overlapped (67% of English test tokens; 70% of Korean test tokens with unreduced /p/). In contrast, English pk clusters are completely different from Korean pk clusters with respect to reduction of p, in that the p never reduces in English, but it often does in Korean (47% of all Korean test tokens).

3.3.2 PERCEPTION

In this section, we will describe a perception experiment employing the results of the production experiment, just presented.

Six English-speaking subjects were employed. All of them were phonology/phonetics graduate students at UCLA.[9] Basically the same methods as in the perception test of Korean pk were employed. Recall that all the experimental phrases used in the production test of English pk (e.g. cheap quality [tʃip kwaləti]) consist of two words having the following segmental sequences:

(14) C_iV_1p kV_2...

C_iV_1k kV_2... (V_1 represents a front vowel; V_2 a back vowel)

Except the phrase-initial consonant (C_i), the remaining parts were extracted from the audio recordings made in the production experiment for English pk. Listening through headphones to three repetitions (with a one-second inter-stimulus interval) of the same token, subjects were asked to choose between V_1pkV_2... and V_1kkV_2... percepts. Subjects were instructed not to guess; if they could not decide, they were allowed not to respond. The subjects were given only one more chance to listen to tokens for which they had not decided in their first attempts.

Eight tokens were culled from each of two major types (p|k and p^k) according to oral pressure patterns. Four out of the eight tokens were from "cheap quality" and the other four tokens were from "keep quiet". Also, control tokens with an underlying kk sequence were chosen from "leek quality" and "seek quiet".

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[9]The subjects were different from those employed in the production experiment. However, three of these subjects were listeners in the perception experiment for Korean pk.

(15) Tokens for perception test of English pk

p|k	p^k	kk
cheap quality	cheap quality	leek quality
cheap quality	cheap quality	leek quality
cheap quality	cheap quality	leek quality
cheap quality	cheap quality	leek quality
keep quiet	keep quiet	seek quiet
keep quiet	keep quiet	seek quiet
keep quiet	keep quiet	seek quiet
keep quiet	keep quiet	seek quiet

In addition, the sole token whose pressure output belongs to the k^p^k pattern was employed.

The results of the perception test by six English-speaking subjects are shown in (16). The table's interior shows the number of tokens whose p was identified by the subjects. The total number of tokens in each cell, if it is not indicated, is four.

(16) Perception of p (English pk)

Frame	Subject	number of cases (out of 4) heard as [pk]			
		p|k	p^k	kk	k^p^k
cheap quality	1	4	3	0	0 (1)
	2	4	4	0	0 (1)
	3	4	4	0	1 (1)
	4	4	4	0	0 (1)
	5	4	4	0	1 (1)
	6	4	4	0	0 (1)
keep quiet	1	4	3	0	
	2	4	4	1	
	3	4	4	4	
	4	4	4	0	
	5	4	4	1	
	6	4	4	1	

Notice that all the subjects identified the p for all the p|k tokens. In the identification test with p^k tokens, only one subject [1] failed in two trials. Thus, as in the perception test of Korean pk, English pk clusters whose pressure outputs display p|k and p^k patterns were perceived as such. These results can be compared with the results of the identification test with the control tokens including underlying kk: kk of most control tokens was perceived as [kk], although one subject [3] mistakenly perceived p for all "seek quiet" tokens, and three other subjects perceived p in one token of "seek quiet". Also, notice that the sole pk cluster which displayed the k^p^k pattern in oral pressure was perceived as pk by two out of six subjects, implying that even a case of extreme overlap does not necessarily yield perceptual assimilation.

Consequently, overall, the results of the perception test with English pk are consistent with those of the perception test with Korean pk in that mere gestural overlap does not obscure the perception of the labial in the consonant cluster pk.

3.4 EXPERIMENT THREE: PRODUCTION OF KOREAN pt

The results reported in section 3.2 have shown that the labial of Korean labial-velar clusters often reduces. We will now consider whether the labial reduction is general in Korean. More specifically, we will determine whether the labial reduction can also occur before coronals by describing a production experiment on pt clusters.

Four Korean native speakers (one female; three males) were recorded. One of them had lived in America two years; two of them seven years; and one of them fifteen years. All of them were more comfortable with Korean than English. These subjects were different from those employed in the production experiment for Korean pk.

The same methods used in the production experiments for Korean and English pk clusters were adopted. As experimental tokens, V_1ptV_2 sequences were employed; V_1 and V_2 represent front and back vowels respectively. Real Korean words with these sequences were placed in phrasal/sentential contexts. Control tokens (V_1pkV_2), which form a minimal pair with test tokens (V_1ptV_2), were also recorded. Appendix III gives a complete list of the phrases/sentences employed. Each phrase was read by the subjects in a casual way three times.

Before reporting the results, we need to consider some limitation of the method employed in the present study. As discussed in section 3.1, articulatory overlap of labial-velar clusters, e.g. ipku, can be reliably detected in oral pressure changes. More specifically, pressure rarefaction indicates a marked overlap of labial-velar clusters: when the tongue body backing due to the front-to-back vowel transition occurs simultaneously with full closures at both the labial and velar places, the sealed oral cavity expands. Is the present method reliable for detecting articulatory overlap of labial-coronal clusters, too? Tongue tip movement for a coronal stop can be somewhat independent of tongue body movement for vowels. In particular, the tongue tip might not retract as much as the tongue body in a front-to-back vowel transition. Thus, tongue tip backing may not always lead to pressure rarefaction even when the closures in pt overlap. Therefore, the method employed in the present study for measuring degrees of gestural overlap is not as reliable for pt tokens as it is for pk tokens. However, the method is still fully reliable in detecting the labial reduction of pt tokens: regardless of degrees of tongue tip backing and articulatory overlap of pt clusters, reduced labials in pt clusters would always result in absence of pressure change. For this reason, pressure results for pt clusters are classified here into two categories, change and no-change. The no-change pattern of pt tokens (<p>t) corresponds to the <p>k pattern of pk tokens in that the labial gesture is reduced.

(17) Results of Korean pt production

	pk				pt	
Subj.	p|k	p^k	<p>k	k^p^k	change	no-change (<p>t)
1	2	3	6	1	12	0
2	0	5	7	0	12	0
3	0	0	12	0	11	1
4	2	0	10	0	12	0
Total	4	8	35	1	47	1

Notice that most pk tokens belong to the <p>k pattern across subjects (shaded area), whereas only one pt token uttered by one subject belongs to the <p>t pattern. These results indicate that no subjects generally reduce the labial of a pt cluster, while many reduce the labial in pk clusters. Thus, we conclude that labial reduction in Korean is not general; it applies before velars, not before coronals.

3.5 Experiment Four: Korean Cross-Word Boundary pk and Prepausal p

In a production experiment with Korean pk clusters, described in section 3.2, all experimental tokens are word-internal, though most of them occur across morpheme boundaries. Let us consider whether cross-word boundary pk sequences behave the same way as word-internal ones in Korean.

We will then consider Korean prepausal p to investigate how general labial reduction is in Korean. The results, which will be reported in 3.5.2, support results of a production experiment with Korean pt tokens reported in 3.4.

3.5.1 Cross-Word Boundary pk

Subjects included four Korean native speakers of the Seoul dialect (two females; two males). One of them had lived in America one year; two of them six years; and one of them ten years.

The same methods used in the earlier production tests were employed. For experimental tokens, $V_1p\#kV_2$ sequences were employed; V_1 and V_2 represent front and back vowels respectively. Real Korean words with these sequences were placed within a phrase/sentential context. Control tokens (V_1pkV_2), which include word internal pk clusters, were also recorded. In Appendix IV is a list of the employed phrases/sentences. Each phrase was read three times by the subjects in a casual way.

Results are summarized in (18):

(18) Results of the production test with Korean word boundary pk

<table>
<tr><th>Subject</th><th>key sequence</th><th>p|k</th><th>p^k</th><th><p>k</th><th>k^p^k</th></tr>
<tr><td>f1</td><td>cross-word</td><td>4</td><td>5</td><td>0</td><td></td></tr>
<tr><td></td><td>word internal</td><td>4</td><td>5</td><td>0</td><td></td></tr>
<tr><td>f2</td><td>cross-word</td><td>0</td><td>1</td><td>8</td><td></td></tr>
<tr><td></td><td>word internal</td><td>0</td><td>2</td><td>7</td><td></td></tr>
<tr><td>m1</td><td>cross-word</td><td>1</td><td>0</td><td>8</td><td></td></tr>
<tr><td></td><td>word internal</td><td>1</td><td>0</td><td>8</td><td></td></tr>
<tr><td>m2</td><td>cross-word</td><td>3</td><td>4</td><td>2</td><td></td></tr>
<tr><td></td><td>word internal</td><td>0</td><td>3</td><td>5</td><td>1</td></tr>
<tr><td>Total</td><td>cross-word</td><td>8</td><td>10</td><td>18</td><td></td></tr>
<tr><td></td><td>word internal</td><td>5</td><td>10</td><td>20</td><td>1</td></tr>
</table>

Notice that <p>k results were produced by all subjects except f1. However, f1 did not produce <p>k outputs for word-internal tokens, either. In other words, if a speaker reduces the labial in the labial-velar cluster within words, s/he does so across words. Consequently, the above results indicate that in Korean, labials in the consonant cluster pk reduce as often across word boundaries as within words.

3.5.2 PREPAUSAL p

The same subjects and method used in the production test of Korean cross-word boundary pk were employed. Regarding experimental tokens, real Korean monosyllabic words ending with labials were employed; e.g. /cip/ 'house'. Subjects were instructed to say the experimental tokens as an answer to an alternative question (e.g. Do you want to live in the house or apartment?). In (19) is a list of the employed phrases/sentences.

(19) Question | Answer

	Question	Answer
a.	(/ap^h-ini twi-ni/)	/ap^h/
	front-or back-or	front
	Is it front or back?	Front.
b.	(/cip-e sa-ni ap^{h}at^{h}ɨ-e sa-ni/)	/cip/
	house-Loc live-or apartment-Loc live-or	house
	Do you live in the house or apartment?	House.
c.	(/ip-ini kõo-ni/)	/ip/
	mouth-or nose-or	mouth
	Is it mouth or nose?	Mouth.

After reading silently the first part of each phrase which is an alternative question (placed in parentheses above), subjects said the second part as an answer to the first part. Each phrase was read three times by the subjects in a casual way. Thus, nine trials were recorded for each subject.

Results were very straightforward: in pressure readings, no change can be observed. In other words, only p|k type outputs emerged. None of the speakers reduced a prepausal p even in a single trial. These results may indicate that Korean speakers do not reduce labials before pause, confirming the conclusion of 3.4 that Korean labial reduction is not general.

3.6 DISCUSSION

3.6.1 A REDUCTION-BASED THEORY OF PLACE ASSIMILATION

For the purpose of investigating the distinct roles of gestural reduction and gestural overlap in consonant place assimilation, we have explored pk clusters in Korean and English. Two principal findings emerged. First, it was found that mere gestural overlap does not yield perceptual place assimilation. Recall that p|k and p^k tokens in both Korean and English were perceived as unassimilated, and even k^p^k tokens were not necessarily perceived as assimilated (this was true of about 50% of the Korean tokens). Second, it was found that in Korean, gestural reduction of the labial gives rise to perceptual assimilation; and further, that labial reduction is not general; it occurs in labials only before velars, neither before coronals nor in the prepausal position. These findings are consistent with those of Nolan's (1992) experiments on English place assimilation in supporting the theory which relies on gestural reduction in explaining casual speech place assimilation. Nolan investigates the role of gestural reduction in English postlexical place assimilation by employing electropalatography. He first divides closure contact patterns of the final alveolar (e.g. /t/ in 'late call') into three basic categories, i.e. full, residual, and zero-alveolars, according to the degrees of reduction. Full-alveolars represent tokens produced with a complete alveolar closure; residual-alveolars tokens produced with a medium closure; zero-alveolars tokens produced with no alveolar closure contact. The perception tests employing these contact patterns show that the reduction degrees of alveolar closure in alveolar-velar or labial clusters are the major negative factors in the identification of the alveolar stop. The identification rate is fairly high with full-alveolars, about 50% with residual-alveolars, and almost zero with zero-alveolars.[10] Thus, Nolan's experiments support the hypothesis that gestural reduction is the main factor giving rise to place assimilation, by showing that in English alveolar place assimilation, extents in reduction of the alveolar closure govern the perception of assimilation.

Let us now consider how the reduction-based theory captures the following casual speech assimilation facts. First, its occurrence is subject to the style and the rate of speech: assimilation occurs more often in casual, fast speech than in formal, slow speech. Second, the manifestations of (casual speech) place assimilation vary across languages and places of target and trigger segments.

The first fact-the speech-rate sensitivity of place assimilation-can be derived from gestural reduction of the target consonant which is also sensitive to speech rate. The results of the present experiments show the rate sensitivity of gestural reduction. As shown in (4), in Korean the labial reduces more often in casual, fast speech than in

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[10]Based on "the finding of better-than-chance performance in zero-alveolar pairs," Nolan (1992:275) claims that "the lexical distinction of alveolar versus nonalveolar does leave traces in the articulatory gesture, even when there is no EPG evidence of an alveolar gesture."

formal, slow speech. Barry (1991) also reports the same speech rate effects in gestural reduction involved in place assimilation, based on the electropalatographic data from speakers of English and Russian. In English, the coronal gesture of corono-velar stop clusters was diminished in magnitude as speech rate increased. Also, the coronal gesture of Russian heterosyllabic clusters consisting of a coronal nasal and a velar stop reduced in magnitude as speech rate increased. These studies show that gestures involved in place assimilation reduce more as speech rate increases. This speech-rate sensitive reduction of the target gesture, which may lead to its perceptual loss, is a type of general gestural reduction of the consonant which is independent of place assimilation. Independently of place assimilation, consonantal gesture typically reduces in magnitude and time in fast, casual speech (Gay 1981). Thus, speech-rate sensitivity of casual speech place assimilation can be a direct result of the independent speech-rate sensitive gestural reduction.

Second, regarding variability in place assimilation, we are concerned with two facts related to conclusions of the present study. First, in Korean, not only coronals but also labials can be targeted in place assimilation, but in English, labials are rarely targeted. Second, in Korean, labials assimilate in place to a following velar, but not to a following coronal. In Experiments One and Two of the present study, it was found that the labials in pk clusters often reduce in Korean, but do not in English. Most tokens with (partially) reduced labials were heard as assimilated. In Experiments Three and Four, it was also found that the labial reduce neither in Korean pt clusters nor in the prepausal position. These results indicate that gestural reduction, which gives rise to place assimilation, can vary across languages and across places of target and trigger segments, suggesting that it does not result directly from vocal tract constraints; rather, it is speaker-controlled.

Barry (1992) and Nolan (1992) elaborate a similar argument. Barry, citing Barry (1991), states that as speech rate increases, the coronal gesture of Russian dental nasals reduces, leading to place assimilation. However, dental stops and velar stops do not tend to reduce in this context. Based on this fact, Barry (1992:399) establishes that low-level processes like gestural weakening in casual speech "are to some extent under the cognitive control of the speaker." Also, as mentioned above, Nolan's (1992) experiments show that gestural reduction is the main factor giving rise to English place assimilation. Based on the fact that place assimilation is not universal, but variable across languages, Nolan further argues that "...they [the facts of place assimilation] must be treated as one of those areas of subcontrastive phonetic detail over which speakers have control..." All these studies suggest that gestural reduction, which is variable under the control of the speaker, is the source of variability in place assimilation. Thus, the two facts characterizing casual speech place assimilation, speech-rate sensitivity and variability, can be direct results of characteristic properties of gestural reduction.

As already mentioned in section 1.2.2.3, these conclusions have some theoretical implications for the theory of articulatory phonology (Browman and Goldstein 1986, 1990, 1992). Among the two explanatory options for casual speech alternations, gestural overlap has been employed as a central mechanism, through manipulating phasing relations of the gestures involved. However, results of the present experiments suggest that we should emphasize the role of the other option, i.e. gestural reduction, but downgrade that of gestural overlap in casual speech place assimilation. Moreover, as opposed to the basic assumption of articulatory phonology, the present results, together with Barry (1992) and Nolan (1992), suggests that gestural reduction giving rise to place assimilation is speaker-controlled; thus, it cannot directly result from physical constraints on the speech mechanism. Thus, it seems that the recent approach of articulatory phonology does not provide an optimal framework for casual speech place assimilation.

3.6.2 Possible Problems With The Method

All interpretations of oral pressure output patterns, whose summary is given in (20), are crucially based on the assumption that the tongue body backing due to the front-to-back vowel transition occurs consistently.

(20) Summary of relations between oral pressure patterns and interpretations (revised from #3)

<table>
<tr><th>Label</th><th>Oral pressure pattern</th><th>Interpretation</th></tr>
<tr><td>(i) p|k</td><td>positive-only</td><td>slight or no overlap</td></tr>
<tr><td>(ii) p^k</td><td>positive-then-negative</td><td>marked overlap</td></tr>
<tr><td>(iii) <p>k</td><td>no-change</td><td>reduction</td></tr>
<tr><td>(iv) k^p^k</td><td>negative-only</td><td>extreme overlap</td></tr>
<tr><td>(v) {p}^k</td><td>positive-then-negative (weak-change)</td><td>partial reduction and marked overlap</td></tr>
</table>

What if this assumption is not true (i.e. tongue body backing does not occur all the time)? This will seriously invalidate the results reported in the present study. For instance, in the case of the pk cluster flanked by front and back vowels (e.g. ipku), no-change pattern (20iii) would occur if velar closure is made before labial closure despite the underlying ordering, and the tongue body does not retract at all. Also, weak-change pattern (20v) would occur if the tongue body retracts only slightly.[11] Then, the pressure patterns interpreted as a type of gestural reduction in the present study can not represent the (partial or complete) labial reduction.

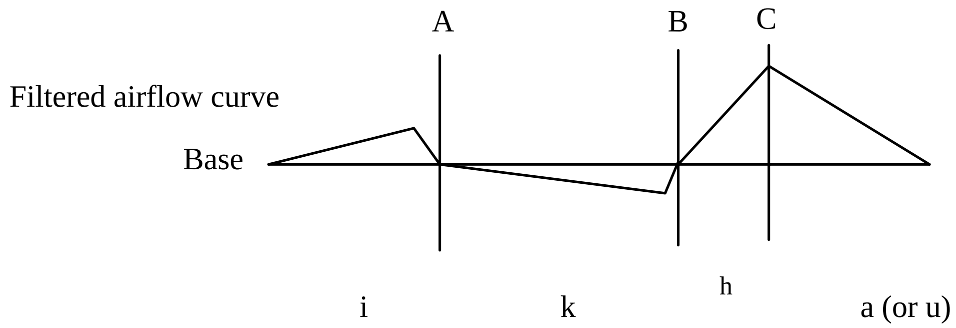
There is some evidence which supports the assumption on the tongue body backing and the interpretations of oral pressure patterns based on it. First, the tongue body backing due to the front-to-back vowel transition has been observed by Barry and Kuenzel (1975). They measured airflow during the production of intervocalic voiceless plosives; plosives are /p, t, k/ and vowel contexts are (a) /a_i/, /u_i/; (b) /i_a/, /i_u/; and (c) /a_a/; /i_i/. Four speakers (one French, one English, two German) were employed reading 'the nonsense words five times each, both normally and at an accelerated tempo'. One of their findings which is about characteristic airflow patterns for [ika] and [iku] is described as follows:

[11]We thank Pat Keating, Peter Ladefoged, and John Ohala for pointing out this possibility to us.

> ...at closure, the AFC [airflow curve] approximates zero; the steady fall during closure takes the AFC considerably below zero [Fig. 3(a), (b)].

The following figure schematizes Fig. 3(a), (b) shown in Barry and Kuenzel pp.230-1:

Fig. 11



The airflow becomes zero at velar closure (Point A). It then steadily decreases up to the velar release (Point B). For the explanation of the observed 'increasingly negative stream' (following Barry and Kuenzel's term), it seems necessary to assume that the tongue body steadily retracts due to the front-to-back vowel transition.[12] Although we do not know whether their subjects behaved consistently without any exception, we believe that characteristic patterns of airflow curve provided by Barry and Kuenzel reflect on at least typical, normal production behavior of their subjects.

In addition, the results of the perception tests in the present Chapter seem to confirm the interpretations for the pressure patterns summarized in (20). If the interpretations for no-change or weak-change patterns (20iii, v) are wrong since the corresponding pressure outputs are actually the result of no, or less, tongue body backing, not labial reduction, then they would pattern, in perception, with any of the other pressure patterns, i.e. (20i, ii, iv). However, as shown in (6-9), results of perception tests on tokens of no-change or weak-change are completely different from those on tokens of the other pressure patterns. How come subjects did not hear the labial only with tokens in which the tongue body did not retract? It is hard to

[12]Barry and Kuenzel (p.275) indicate that in addition to tongue retraction, jaw lowering might also play a role in the observed airflow decrease for /ika/; but jaw movement is negligible for /iku/.

imagine that tongue body backing affects the perception of the labial.

In conclusion, the assumption that the tongue body retracts consistently during the production of pk flanked by front and back vowels seems valid; thus, the interpretations of pressure patterns which we have provided on the basis of this assumption are also valid.

3.7 Conclusion

We performed the present experiments for the purpose of determining the articulatory and perceptual mechanisms involved in gradient casual speech assimilation. The more specific aim was to find out which articulatory process -- gestural reduction or gestural overlap -- is mainly responsible for the perceptual loss of the target in place assimilation. Results suggest that gestural reduction plays the decisive role in the perceptual loss of the target in place assimilation. In Chapter Four (where we propose a formal theory of speech production within the framework of Optimality Theory), this conclusion will be incorporated in establishing the Weakening constraint (See section 4.1), which effect the perceptual loss of the target in place assimilation.

Chapter 4

Constraints

In Chapter Two we concluded that attested patterns of place assimilation are variable, but they may be characterized by implicational statements (Ch. 2 #54). In this Chapter we provide an explicit formal analysis for such variable, but constrained, patterns of place assimilation. In section 1.3, we claimed that the variable, but constrained, patterns of place assimilation result from diverse ways of reconciling two conflicting groups of constraints (i.e. articulatorily based constraints and perceptually based constraints) which conspire to produce the optimal output in speech production. We now provide the two main groups of universal constraints and universal rankings of perceptually based constraints. We then demonstrate how the present approach can analyze attested patterns of place assimilation.

4.1 WEAKENING

As shown in (2) of Chapter One (repeated below), place assimilation in consonant clusters can be decomposed into two parts, loss of the gesture encoding place of articulation in the target segment (1a) and lengthening of the corresponding gesture in the trigger segment (1b):

(1)	Input	C_1C_2	
a.	<u>loss of target</u>	Ø	
b.	<u>lengthening of trigger</u>	C_2C_2	(Output)

This section is concerned only with the loss of the target gesture (1a). In Chapter Three, we investigated the articulatory process that yields gradient place assimilation in Korean. Results indicate that gestural reduction is the articulatory process which is responsible for the perceptual loss of the target gesture; further, this reduction is speaker-controlled. Recall that these results are consistent with those of Nolan's (1992) experiments on English casual speech place assimilation.

Based on the results of these experiments, we claim that gestural reduction is the articulatory process which is responsible for the perceptual loss of the target in casual speech place assimilation. This claim can be easily extended to categorical place assimilation, in which the target gesture is maximally reduced. This reduction process itself is not confined to place assimilation. Independent of place assimilation, the consonantal gesture typically reduces in magnitude and duration in fast, casual speech (Gay 1981). Variability of consonant reduction depending on the speed and style of speech seems to parallel gradiency of consonant place assimilation which also depends on the speed and style of speech. Thus, we conclude that gestural reduction which yields place assimilation is a type of general consonantal reduction.

Why do speakers reduce consonantal gesture in casual speech? We assume that this is due to a demand governing speakers' speech production behavior, i.e. 'to minimize articulatory effort'. This demand can be formulated in the following constraint[1]:

(2) Weakening Constraint

Conserve articulatory effort.

The Weakening constraint has the effect of reducing the magnitude of the target gesture. If it applies to one member of a consonant cluster, this member may lose its perceptual properties, leading to place assimilation.

4.2 PRESERVATION CONSTRAINTS

In this section, we provide Preservation constraints which conflict with the proposed Weakening constraints, while discussing the acoustic facts which can be observed in place assimilation typology. As discussed in section 1.3 (#35), we assume the Production Hypothesis, repeated below:

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[1]Kirchner (1994) provides the same type of constraint, termed LAZY.

(3) Production Hypothesis

Speakers make more effort to preserve the articulation of speech sounds with powerful acoustic cues, whereas they relax in the articulation of sounds with weak cues.

From this, a general strategy for ranking preservation constraints follows: constraints preserving acoustically more salient segments must be ranked above those preserving acoustically less salient segments. Based on this strategy, we propose the following formalization of Preservation constraints and their internal rankings:

(4) Pres(X(Y)): Preserve perceptual cues for X (place or manner of articulation) of Y (a segmental class).

Universal ranking: Pres(M(N)) >> Pres(M(R)),

where N's acoustic cues for M are stronger than R's cues for M.

Notice that Preservation constraints for consonantal gestures with strong acoustic cues are more highly ranked than those with weak cues. In the following sections, with (4) in hand, we provide sets of Preservation constraints classified by several categories, while discussing the hierarchy in the acoustic effects within each category.

4.2.1 CONSTRAINTS PRESERVING PLACE CUES

Let us consider Preservation constraints which have the effect of preserving the magnitude of a constriction producing place cues; in other words, in (4), X = place.

4.2.1.1 MANNER CONSTRAINTS

In this section, we discuss the acoustic hierarchy of continuants (nonnasal sonorants and fricatives) and noncontinuants (stops and nasals) when they are the first constituent of a consonant cluster.

As discussed by Borden and Harris (1984), the place cues for stops are the formant (mainly F2) transitions of neighboring vowels and the release burst. As shown by Malécot (1958), the release burst plays a powerful role in the identification of a point of articulation. In the consonant cluster C_1C_2, if C_1 is a stop, it is unreleased due to its overlap with C_2 in many languages (most languages surveyed in the present study). Unreleased stops lack the prominent place cues in the burst. Thus, formant transitions out of the preceding vowel are the only available place cues for these stops. In contrast, if C_1 is a continuant, i.e. a fricative or a nonnasal sonorant (glide and liquid), its place cues are well preserved even when overlapping with C_2. Place cues for fricatives are encoded not only in the vowel formants but also in the friction. As stated by Borden and Harris (1984:192), "frequency of the noise indicates place of articulation even when extremely brief..."; thus, a short period of non-overlapping frication at the beginning of the fricative provides sufficient place cues for fricatives. Thus, fricatives have more prominent place cues than stops or nasals. Hura, Lindblom, and Diehl (1992) carried out perception tests to compare English fricatives, stops and nasals in confusability when occurring before a stop. Their results indicate that fricatives were less confusable than stops and nasals. Also, as the name 'glide' suggests, the critical acoustic cues for glides and liquids are (somewhat gradual) frequency changes, mainly in F2. Thus, frequency changes in the neighboring vowel through non-overlapping resonance provide sufficient cues for the place identification of glides and liquids. Nonnasal sonorants overlapping with C_2 which may obscure their steady-state portion do not significantly undermine the place identification.

In conclusion, it seems that continuant consonants-fricatives and nonnasal sonorants-have more robust place cues than stops in the consonant cluster when occurring as the first member of a consonant cluster.

Let us compare the acoustic effects of nasals and stops with respect to place cues. It has been argued in the literature (Malécot 1956; Nord 1976; and Recasens 1983 among others) that for nasals, formant transitions of the following vowel are the prominent place cue, in comparison with the murmur. A different claim about place cues for nasals is proposed by Kurowski and Blumstein (1984): the murmur and transition surrounding the nasal release provide the most reliable place cues but neither the murmur immediately preceding the release alone nor the transition immediately following the release alone provides a sufficient place cue for the nasal. To determine the perceptual roles of the nasal murmur and transition in identifying place of articulation, Kurowski and Blumstein basically compared three types of conditions involving NV sequences: (i) the murmur preceding the release, (ii) the transition following the release; and (iii) the mixed condition, i.e. the murmur and transition surrounding the nasal release. Results indicate that only the mixed condition is sufficient cue for the nasal's place of articulation; the other two conditions, which did not show a significant difference, do not possess sufficient cues. In the NC cluster, the nasal is typically unreleased under its overlap with the following consonant (obstruents or nasals). The overlap of NC obscures the murmur and the transition around the release which, Kurowski and Blumstein claims, is the most reliable place cue. Place information of the nasal can be found only in the transition from the vowel to the nasal. This transition seems, in general, perceptually weak. (See section 4.2.1.3 for discussion which indicates that VN transitions are acoustically weaker than NV transitions.) Nasal consonants are acoustically characterized by resonance of the pharyngeal and nasal cavities, and antiresonances of the oral cavity (Borden and Harris; Ohala and Ohala 1993:233-4). The resonance is low, below 500 Hz (Borden and Harris p.180). And, resonance and antiresonance may cancel each other if close in frequency. Thus, "the obvious change in spectrum from an orally produced vowel to a nasal includes...a weakening of the upper formants [F2,3,...]" (Borden and Harris p.180). Such weakening of the upper formants can lead to weakening of place cues in the vowel-to-nasal transition, implying that nasals have weak place cues in the V-C transitions, in comparison with stops.

More directly relevant data can be seen in Malécot (1956). Malécot carried out a perception test employing a tape-splicing technique. He separated and recombined the parts for nasal resonance and its neighboring vowel of utterances recorded on magnetic tape. The results of his perception tests (table 2, 4, 5) show that vowel transitions of stops spliced onto the nasal resonance ($V_1C + V_2N \dashrightarrow V_1N$) dominate the perception of place of articulation for the following nasals (N) more consistently than those of nasals spliced onto other nasal resonances ($V_3N_1 + V_4N \dashrightarrow V_3N$); in other words, listeners determined the place of N more consistently on the basis of V_1 than V_3. These results suggest that vowel transitions of stops are a stronger place cue than those of nasals, that is, nasals have acoustically weaker place cues than stops. Nasals' confusability, compared to stops, has been shown by Fant (1968:236-253) and Mohr and Wang (1968), both cited by Hura, Lindblom and Diehl (1992).

In summary, unreleased nasals have weaker place cues than unreleased stops, which in turn have weaker cues than continuants. This hierarchy in strength of acoustic cues leads to the following ranking among constraints which formulate preservation of perceptual cues for place of continuants, stops, and nasals:

(5) Universal ranking for target manner

$$\text{Pres(pl(}\underset{[+\text{cont}]}{\underline{\qquad}}\text{ C))} \gg \text{Pres(pl(}\underset{[\text{stop}]}{\underline{\qquad}}\text{ C))} \gg \text{Pres(pl(}\underset{[\text{nas}]}{\underline{\qquad}}\text{ C))}$$

These constraints have the effect of preserving the magnitude of a constriction producing place cues. Notice that the ranking in (5) mirrors the implicational statements about target manner of place assimilation (Ch. 2 #54a), repeated below:

Target manner

(i) If fricatives or non-nasal sonorants are targets of place assimilation, so are stops.

(ii) If stops are targets of place assimilation, so are nasals

4.2.1.2 Place Constraints

Let us discuss the acoustic hierarchy among coronals, labials and velars when they are unreleased. As discussed above, for unreleased stops and nasals, the vowel transitions are the primary place cues. Byrd (1994:70), briefly discussed in section 1.3, has established the argument that a coronal, specifically **d**, has perceptually weak cues, when she explains the observed difference in overlap duration between **dg** and **gd**; dg is more overlapped than gd:

> So, why should **dg** be more overlapped than **gd**? We suggest that speakers will make less of an effort to preserve less robust perceptual cues. Because the cues for the unreleased **d** are so weak to start with, there is little motivation for the speaker to preserve them. Even a little adulteration from C2 can overwhelm them. The formant transitions for **d** show relatively small excursions (Öhman, 1967), don't have a large effect on F3, and have an articulation, and hence, formant movement, that is relatively rapid (Kuehn and Moll, 1976).

Ladefoged (1975:179) also states that a coronal stop "produces a comparatively small movement of the formants," displaying spectrograms of the words 'bab, dad, gag', in which the formants (F2 and F3) of the vowel flanked by the labials display a rapid increase followed by a rapid decrease; Those flanked by velars display a noticeable convergence of F2 and F3. However, those flanked by coronals display 'a very slight fall'. Although it still needs to be investigated whether coronals show small transition movements with back vowels as well, the observed relatively small movements of the front vowel implies that unreleased coronals are acoustically weaker than unreleased velars and labials, since smaller formant changes must be acoustically less prominent than larger changes.

As mentioned by Byrd (cited above), more convincing evidence for the acoustic weakness of an unreleased coronal can be attributed to its high velocity. Tongue tip gestures are rapid; thus, they have rapid 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.

Also, there seems to be a difference in robustness of place cues between velars and labials (and coronals). Unlike labials and coronals, velars have an acoustic attribute, i.e. compactness (Jakobson, Fant and Halle 1963). As mentioned by Ladefoged, cited above, velars can be characterized by a noticeable convergence of F2 and F3 of a neighboring vowel. These two formants can form a prominence in the midfrequency range. As argued and discussed by Stevens (1989:17-18), such a midfrequency prominence of velars can form a robust acoustic cue for place of articulation: "perturbations in the place of articulation for the velar consonant are not expected to modify greatly the basic acoustic attribute of a midfrequency spectral prominence that is a consequence of the two converging formants." As we understand Stevens, listeners do not have to know the exact target points of F2 and F3 transitions to identify velars; mere convergence of two formants will provide a sufficient cue, regardless of where they converge into. Based on Stevens's claim, we assume that velars have an additional acoustic cue, i.e. compactness, for place of articulation, compared to coronals and labials.

In summary, coronals, labials, and velars are acoustically strong in increasing order when they are unreleased. Based on this acoustic hierarchy, I propose the following ranking for preservation constraints which formulate the preservation of perceptual cues for place of unreleased coronals, labials, and velars:

(6) Universal ranking for target places

Pres(pl(dor˺)) >> Pres(pl(lab˺)) >> Pres(pl(cor˺))

This ranking indicates that place cues of unreleased velars must be preserved in preference to those of unreleased labials, which are, in turn, preserved in preference to those of unreleased coronals. It indirectly captures the implicational statements about target place of place assimilation (Ch. 2 #54b).

4.2.1.3 Position Constraints

It has been claimed in the literature (Bladon 1986; Manuel 1991; Ohala 1990, 1992 among others) that syllable onset consonants are acoustically stronger than syllable coda consonants. This claim is based on acoustic facts involving mainly stops and nasals: CV transitions are acoustically more salient than VC transitions.

For noncontinuants, i.e. stops and nasals, high pressure builds up at their offset. Their release occurring into vowels are a prominent acoustic cue for the place of articulation. As mentioned above, it is well known that stop release bursts are a prominent place cue (Malécot 1958).

Manuel (1991) also established the claim that nasal release is a salient place cue (Notice that this claim can be compatible with the experimental results of Kurowski and Blumstin (1984), discussed in section 4.2.1.1). For nasals, velum is lowered during the oral closure. When the oral cavity is opened and closed, the F2 transition, which is a place cue for the consonant, is displayed. The prominence of the F2 transition depends on the degree of velum lowering. If the velum is very low, most energy will go through nasal cavities; thus, the F2 transition, an acoustic consequence of oral constriction change, will be very weak. In contrast, if the velum is not so low, allowing some amount of energy into the oral cavity, the F2 transition will be salient. Based on other studies (e.g. Ushijima and Sawashima 1972) which suggest that "the velum is generally lower at the time the oral constriction is being made for a syllable-final nasal consonant than it is at the time oral constriction is released for a syllable-initial consonant," Manuel states that syllable-final nasals are perceptually less salient than syllable-initial nasals.

Based on the above discussion, we conclude that the CV transition is acoustically stronger than the VC transition (notice that this is mainly based on the discussion with stops and nasals; thus, it needs further investigation of continuants to become a fully general statement). Thus, in a sequence VC_1C_2V, C_1, i.e. coda, is acoustically weaker than C_2, i.e. onset; onsets have stronger place cues than codas. The acoustic strength of onsets over codas leads to the following universal ranking in constraints which formulate the preservation of place cues for consonants in different syllable positions:

(8) Universal ranking for positions

Pres(pl(onset)) >> Pres(pl(coda))

This ranking indicates that place cues for onsets must be preserved in preference to those for codas. Thus, it will have the effect of preserving the articulatory magnitude of the onset more than that of the coda, which indirectly captures the implicational statement about syllable position of place assimilation targets (Ch. 2 #54c, i.e. if onsets are targets, so are codas).

4.2.1.4 Trigger Place Constraints

In this section, we discuss the acoustic salience of place cues for the first constituent of a consonant cluster which 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) and Zsiga (1992), although C_1 is usually stronger than C_2. In a consonant cluster C_1C_2, C_2 of different places may obscure place cues of the C_1 to different degrees. We claim 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; cf. Byrd (1992) assumes that "a slower movement might prove more difficult to hide," following Browman and Goldstein (1990). The schematic representations in (9) can illustrate how slow gestures would obscure place cues for a neighboring gesture more than rapid gestures.

(9)

V1 C1 C2

a.

rapid gesture

b.

slow gesture

In (9a), a rapid gesture slightly overlaps with the preceding consonantal gesture; so, C2's influence onto V1-to-C1 formant transitions would be minimal. However, in (9b), a slow gesture C2 may begin even before the C1 gesture does; thus it will greatly obscure not only C1 gesture itself but also the formant transitions of V1-to-C1. Therefore, a slower gesture will obscure the place cues of a neighboring consonantal gesture more easily. As discussed above, 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. We now propose the following universal ranking in constraints which formulate the preservation of place cues for C_1 before coronals and noncoronals:

(10) Universal ranking for trigger places

Pres(pl(__cor)) >> Pres(pl(__noncor))

This ranking indicates that place cues of a consonant must be preserved before coronals in preference to before noncoronals. Thus, it has the effect of preserving articulatory magnitude of the consonant occurring before coronals and noncoronals in the decreasing order. This resulting effect indirectly captures an implicational statement about trigger place of place assimilation (Ch. 2 #54e, i.e. if coronals trigger place assimilation, so do velars), although it predicts more than the surveyed cases: those involving labials as an asymmetric trigger or non-trigger are not known.

4.2.1.5 Trigger Manner Constraints

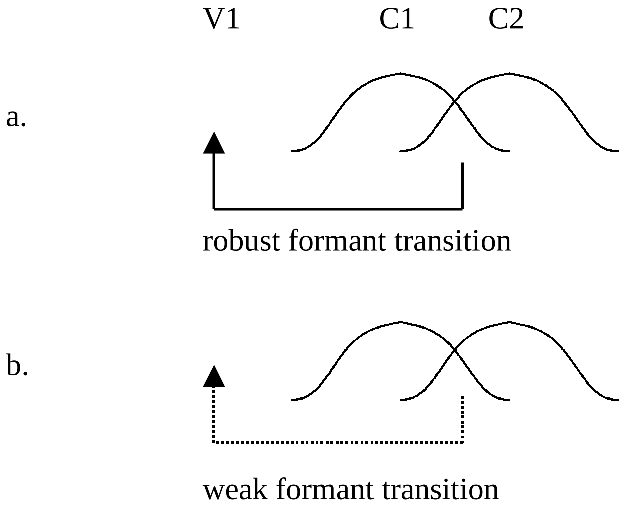
In a cluster C_1C_2, the acoustic salience of place cues for C_1 may vary depending on the manner of articulation of the C_2. When C_1 is a stop or a nasal, there is a significant difference in obscuring its place of articulation between nonnasal sonorants and the other consonants, stops, nasals and fricatives occurring in the C_2 position. Stops and nasals are typically released before nonnasal sonorants, liquids and glides. As discussed above, stops have prominent place cues in the release burst. Also, as discussed above, nasals seem to have prominent cues around the release (Kurowski and Blumstein 1984; Manuel 1991). Thus, in the contexts of nonnasal sonorants in the C_2, the prominent place cues in the release of stops and nasals occurring in the C_1 position can be maintained. In contrast, in many languages, consonants are unreleased before stops, fricatives and nasals; they will lose the most prominent place cue in the release. Thus, consonants (stops and nasals) have acoustically stronger place cues before nonnasal sonorants than before stops, nasals, and fricatives.[2]

Let us compare stops and nasals when they occur as the second constituent of consonant clusters. As discussed in the previous section, in the sequence $V_1C_1C_2$, the formant transitions of V_1 are affected by both C_1 and C_2. It has been claimed

[2]Notice that in most of our surveyed patterns of place assimilation (Ch. 2), only nasals (and stops) are targets.

there that C_2 with slow movements would overlap more with C_1, obscuring the C_1's place cues in the V1-to-C1 formant transitions. If the inherent velocity is same for two gestures, what makes a difference in obscuring place cues for C_1? As schematized in (11), C_2 whose place cues are robust in the formant transitions is likely to affect the formant transitions of V_1, obscuring place cues of C_1.

(11)



Under this speculation, if we consider the conclusion of section 4.2.1.1, i.e. that stops have more robust place cues in the formants of neighboring vowels than nasals, it follows that the place cues of C_1 can be obscured more before stops than nasals.

However, we have no idea about whether transitions of a vowel into fricatives are more robust than those of stops or nasals. It has been claimed in the literature (Harris 1958; Grimm 1966; and Mann and Repp 1980) that fricatives (mainly nonsibilants) have place cues in the vocalic transition, too. Thus, we will rank fricatives only above nonnasal sonorants in obscuring the C_1's place of articulation, leaving its ranking with respect to stops or nasals undecided.

Our discussion leads to the following universal ranking of constraints which formulate the preservation of place cues for C_1 before stops, nasals, fricatives and nonnasal sonorants:

(12) Universal ranking for trigger manner

Pres(pl(__[+son, -nas])) >>

Pres(pl(__fric)), [Pres(pl(_nas)) >> Pres(pl(__stop))]

This ranking indicates that place cues of a consonant occurring before nonnasal sonorants must be preserved in preference to those of a consonant before nasals, fricatives and stops; those of a consonant before nasals in turn must be preserved in preference to those of a consonant before stops, but relative ranking of fricatives is not known. Notice that the ranking (12) can cover implicational statements about trigger manner in (Ch. 2 #54d), repeated below, although it predicts more.

d. <u>Trigger manner</u>

(i) If nonnasal sonorants trigger place assimilation, so do nasals and fricatives

(iii) If nasals or fricatives trigger place assimilation, so do stops.

We hope that the future research proves that fricatives have weaker vocalic transitions than stops.

4.2.2. CONSTRAINTS PRESERVING MANNER CUES

We are now in a position to consider preservation constraints which have the effects of preserving the magnitude of a constriction producing manner cues. A constraint can be proposed for each manner cue. Some constraints preserving manner cues are shown in (13).

(13) ('mnr' represents 'manner')

a. Pres(mnr(+nas)): Preserve perceptual cues for nasality

b. Pres(mnr(-nas)): Preserve perceptual cues for orality

c. Pres(mnr(+cont)): Preserve perceptual cues for continuancy

d. Pres(mnr(-cont)): Preserve perceptual cues for noncontinuancy

We can extend these, somewhat simplified, constraints preserving manner cues to those involving contextual factors as we did with those preserving place cues in section 4.2.1. For instance, we can propose constraints, Pres(mnr($\overline{\text{[-nas]}}$ +nas)) and Pres(mnr($\overline{\text{[+nas]}}$ -nas)), which preserve orality of a consonant occurring before a nasal and nasality of a consonant occurring before an oral consonant, respectively. These constraints can be ranked according to the strategy formulated in (4). If orality is acoustically weak before a nasal but nasality is acoustically strong before oral consonant, then we can have the following universal ranking:

(14) Pres(mnr($\overline{\text{[+nas]}}$ -nas)) >> Pres(mnr($\overline{\text{[-nas]}}$ +nas))

If this ranking can be supported by the experimental data, it may provide an account for asymmetric behavior between nasal and oral spreadings which can be seen in the following examples from Korean; i.e. nasals spread onto the preceding oral consonant, but orality never spreads onto the preceding nasal consonant:

(15) Korean nasal spreading

a.	/mit+na/	-->	[minna]	'believe + question ending'
b.	/kuk+mul/	-->	[kuŋmul]	'soup + water'
but,				
c.	/min+ta/	-->	[minta]	'push + SE'
			*[mitta]	
d.	/kaŋ+pota/	-->	[kaŋpota]	'river + rather than'
			*[kakpota]	

These patterns will be derived by ranking the Weakening constraint between the two preservation constraints in (14). Notice that this type of regressive nasal spreading can be seen in many other languages, Latin (Palmer 1954), Malay and Thai (Lodge

1992), Pali (Hankamer and Aissen 1974), West Greenlandic (Rischel 1974).

However, we will not go into any more details about the ranking of constraints preserving manner cues, since the focus of the present study is place assimilation. We will discuss preservation of manner cues only in relation to place assimilation, leaving the in-depth discussion of preservation of manner cues for the future research.

Let us consider what aspects of place assimilation can be affected by the preservation of manner cues. Not only categorical place assimilations but also gradient ones have been assumed in the literature to display compensatory lengthening of the target segment, as suggested by descriptions of gradient assimilation: e.g. 'late call' /leyt kɔl/ --> [leyk kɔl]. This lengthening of the trigger in gradient place assimilation has been demonstrated by Barry's (1991) electropalatographic study on English postlexial place assimilation. In that study, he investigates various temporal aspects for English [n g] sequence in the phrase hand grenade. In his comparison of the slow and fast utterances, he (p.15) reports that in the fast utterance, "the coronal gesture is diminished in magnitude to such an extent that no closure is formed, and also somewhat in duration"; on the other hand, "[the duration of the velar closure] increases by 78 % and [the overall duration of the dorsal gesture] increases by 43 %." The data of Byrd (1994) confirm this lengthening of the trigger in English place assimilation. Byrd investigates articulatory timing in English consonant sequences by employing electropalatography. In that study employing five American English speaking subjects, the percentage of contacted electrodes in front and back regions of the palate were measured. Contact patterns in the front region indicated contact for a coronal obstruent and contact patterns in the back region indicated contact for a velar stop. To determine whether there is any correlation between the reduction of the coronal stop and duration of the velar stop in coronal#velar stop clusters, we can examine Byrd's eletropalatographic data on the English coronal#velar stop sequence (*dg*). In her measurements, the duration of a stop segment is represented by the duration of contact in the region, i.e. "time of final contact [in a region] - time of initial contact [in the same region]." Also, the magnitude reduction of a stop can be indicated by "peak contact" which is "the maximum percent contact in a region." A regression of peak *d* contact against *k* contact duration yields a significant linear fit ($p = .0137$) with an r^2 of .17 (n=35).[3] This regression indicates that in English /d#g/ clusters, the reduction of /d/ is somewhat accompanied by a lengthening of /g/.

Based on Barry (1991) and Byrd (1994), we now assume that in gradient place assimilation, as the target consonant reduces, the trigger consonant lengthens. Let us consider why the compensatory lengthening effect occurs in place assimilation. What could be the motivation for this compensatory lengthening? The compensatory lengthening occurring in gradient place assimilation is different from that observed in categorical assimilation in that the lengthening itself is gradient, due to the gradient reduction of the target segment. Nonetheless, as the term 'compensatory lengthening' suggests, both types of compensatory lengthening operate for the same reason. We believe that the goal of the compensatory lengthening of place assimilation is to maintain the manner cue of the target gesture. More specifically, when a stop is the target, lengthening silence from the trigger gesture will have the effect of preserving manner cues of the target gesture.

(16)

a.	<u>Articulation</u>	t k		{t} K
	tongue tip	[-----------]	===>	[--]
	tongue body	[-----------]		[----------------------]
b.	<u>Perception</u>	[<------silence------->]	===>	[<------silence------->]

(Capital letter denotes lengthening; { } reduction in time and magnitude.)

In (16a), the dashed line represents the stop closure gesture which is acoustically silent, as represented in (16b). By comparing the left and right sides of the arrow, we observe that the tongue tip closure gesture is reduced and that the tongue body closure gesture lengthens. The stop closure is acoustically silent; thus, there would not be any loss of the stop manner cue, i.e. silence. In other words, to obey the constraints in (13), a constituent C_2 of consonant clusters C_1C_2 lengthens as the C_1

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[3]We thank Dani Byrd for providing this regression analysis with data from her dissertation for me.

reduces.[4] Recall that Preservation constraints must be evalutated on their perceptual consequences. Thus, the constraints in (13) are indirectly responsible for the compensatory lengthening of place assimilation.

Thus far, we have tried to explain the phenomena related to the compensatory lengthening in place assimilation mainly by relying on preservation of manner cues.

Let us summarize all constraints (and universal rankings) which we have proposed thus far:

(17) Summary of constraints and their universal rankings

a. **Weakening** constraint

Conserve articulatory effort.

b. **Preservation** constraints

Pres(X(Y)): Preserve perceptual cues for X, place or manner of articulation, of Y, a segmental class.

Universal ranking: Pres(M(N)) >> Pres(M(R)),

where N's acoustic cues for M are stronger than R's cues for M.

(i) **Place**

Universal ranking for target manner

Pres(pl($\overline{}_{[+cont]}$ C)) >> Pres(pl($\overline{}_{[stop]}$ C)) >> Pres(pl($\overline{}_{[nas]}$ C))

Universal ranking for target places

Pres(pl(dor˺)) >> Pres(pl(lab˺)) >> Pres(pl(cor˺)).

Universal ranking for syllable positions

Pres(pl(onset)) >> Pres(pl(coda))

Universal ranking for trigger place

Pres(pl(__cor)) >> Pres(pl(__noncor))

---

[4]Lengthening of C_2 will violate the low-ranked constraint which requires preservation of the canonical duration of an underlyingly singleton consonant.

Universal ranking for trigger manner

Pres(pl(__[+son, -nas])) >>

Pres(pl(__fric)), [Pres(pl(_nas)) >> Pres(pl(__stop))]

(ii) **Manner**

Pres(mnr(+nas)): Preserve perceptual cues for nasality

Pres(mnr(-nas)): Preserve perceptual cues for orality

Pres(mnr(+cont)): Preserve perceptual cues for continuancy

Pres(mnr(-cont)): Preserve perceptual cues for noncontinuancy

Notice that each set of constraints preserving place cues (17bi) has the inherent ranking defined in terms of their acoustic effects. This ranking is universal; it cannot be altered. What can change is not ranking within a set of constraints classified by the same criterion, but the interaction among sets of constraints, each of which is classified by different criteria. Consequently, actual patterns of place assimilation will be determined by the interaction of those sets of constraints, maintaining the universal ranking within each set. Notice that the above universal rankings make predictions about possible and impossible patterns of place assimilation. For instance, the universal ranking for target manner predicts that if stops are targets of place assimilation, nasals are also targets; but it does not predict that in any language, only stops are targets, excluding nasals. These predictions are compatible with implicational statements on place assimilation in Ch. 2 #54, except the following two cases. First, the ranking for trigger place predicts an asymmetry between coronals and labials which is not supported by our survey. Second, the ranking for trigger manner is not complete, since we could not decide the relative hierarchy between fricatives, on the one hand, and nasals and stops, on the other hand. Thus, the generalization that stops are a more likely trigger than fricatives is not covered. We hope future research will cover these cases.

4.3 ANALYSES

Our mechanism, just presented, can analyze all patterns of surveyed languages shown in Chapter Two. To demonstrate how, in this section, we show the analyses of patterns attested in Malayalam, English and Korean. These languages display different interesting properties about place assimilation. Malayalam place assimilation displays asymmetries not only in trigger manner but also in target manner: only nasals can be targeted and only stops can trigger. English assimilation shows the coronal-noncoronal asymmetry in target place. It also shows seemingly independent coronal coda weakening which must be analyzed along with place assimilation. Finally, Korean assimilation displays the labial-velar asymmetry in target place and the coronal-velar asymmetry in trigger place.

4.3.1 MALAYALAM

Malayalam place assimilation has been discussed in Chapter Two. Its important points are summarized in (18).

(18) a. Only nasals can be targeted.

b. Only stops can trigger place assimilation.

c. Only codas can be targeted.

To explain these facts in Malayalam, we propose the following ranking:

(19) Pres(mnr(nas)), Pres(mnr(-cont)), Pres(pl($\underset{\text{[stop]}}{\overline{\quad\quad}}$ C)), Pres(pl(onset)), Pres(pl(__nas)) >> **Weakening** >> Pres(pl($\underset{\text{[nas]}}{\overline{\quad\quad}}$ C)), Pres(pl(coda)), Pres(pl(__stop))

Notice that all the interesting asymmetries displayed in Malayalam place assimilation (18) can fall out from (19). In (19), constraints, which preserve nasal codas, codas in general, and a consonant occurring before a stop, are ranked below the Weakening constraint; thus they may be reduced. In contrast, constraints which preserve stop codas, onsets in general, and a consonant occurring before a nasal are ranked above the Weakening; thus, they never be reduced. Consequently, only coda nasals occurring before a stop can be reduced. Also, notice that all universal rankings for Preservation constraints summarized in (17bi) are observed; e.g. Pres(pl(onset)) >> Pres(pl(coda)). The analysis of Malayalam place assimilation can be illustrated by the table in (20). Only the mid consonant cluster is considered in assessing violations of constraints. Due to the limited space, inessential constraints are omitted; e.g. Pres(pl(__nas)). The following notations are employed from Prince and Smolensky (1993): ☞ indicates an optimal output; solid vertical line indicates that the constraint on its left side dominates the one on its right side; weak vertical line indicates a tie in ranking; ! indicates "the crucial failure for each suboptimal candidate, the exact point where it loses out to other candidates" (Prince and Smolensky p.18).

[sam [giitam]] --> saŋgiitam (from Ch. 2 #32a)

(20)

	Candidates	Pres(mnr (nas))	Pres(mnr (-cont))	Pres(pl (onset))	Weak	Pres(pl([nas]___ C))	Pres(pl (coda))
☞	sa**ŋ** giitam				*	*	*
	sam giitam				**!		
	sa giitam	*!	*		*	*	*
	sam **p**iitam			*!	*		

The correct output saŋgiitam violates only lower-ranked constraints: it violates Weakening once due to the preservation of the onset gesture, i.e. velar. All the other candidates violate either higher-ranked constraints or Weakening twice. Notice that constraints preserving manner cues, i.e. Pres(mnr(nas)) and Pres(mnr(-cont)), have the effect of compensatory lengthening. To maintain manner cues of the target nasal /m/, the closure of the trigger stop /g/ is lengthened.

4.3.2 English

As discussed above, English alveolar stops optionally assimilate in place to following labial and velar stops (21a,b), but labials and velars rarely assimilate to a following consonant (21c,d):

(21) English Place Assimilation

a.	red car	/red ka:/	[reg ka:]	
b.	green paint	/gri:n peint/	[gri:m peint]	(Nolan 1992:262)
but,				
c.	leap quickly	/lip kwikli/	[lip kwikli]	
			*[lik kwikli]	
d.	jack pot	/dʒæk pat/	[dʒæk pat]	
			*[dʒæp pat]	

As shown in many studies (Barry 1985, 1991; Browman and Goldstein 1990; Nolan 1992; and Byrd 1994), this postlexical place assimilation is gradient.

Independently of the place assimilation, English alveolar stop reduces in the coda position, being subject to the concomitant glottalization (22a).

(22) English coda reduction

a. what [wʌt] ~ [wʌt^{ʔ}] ~ [wʌʔ^{t}] ~ [wʌʔ] (Hayes 1992:285)

but,

b.	cap	[kæp]	*[kæ^{p}]
c.	kick	[kik]	*[ki^{k}]

Notice that not every English coda which is typically unreleased is subject to reduction (22b,c). Only alveolar codas are subject to this reduction; labial and velar codas are rarely subject to this coda reduction. This coda reduction is optional and gradient, just like alveolar stop place assimilation. The target, the coronal stop, is common in the two processes, alveolar coda reduction and place assimilation. Thus, we believe that these similarities are not an accident; they have the common origin of alveolar reduction. An analysis of English place assimilation should capture this coincidence. Following Hayes (1992), we claim that English place assimilation and alveolar coda reduction are actually derived from the one and the same process, i.e. gestural reduction of alveolar stops in the coda position. (See the discussion in section 1.2.2.1 for Hayes's analysis.)

To provide a unified analysis of English place assimilation and alveolar coda reduction, we propose the following ranking among constraints:

(23) Ranking for English place assimilation

Pres(mnr(-cont)), Pres(pl(dor˺)), Pres(pl(lab˺)), Pres(pl(onset))

>> **Weakening** >> Pres(pl(cor˺)), Pres(pl(coda))

This ranking indicates that coronal codas can be reduced, since constraints which preserve coronals and codas are ranked below the Weakening constraint. Notice that all universal rankings within each set of constraints summarized in (17) are observed; e.g. Pres(pl(lab˺)) >> Pres(pl(cor˺)). The single ranking (23) will explain the two seemingly different processes - place assimilation and alveolar coda reduction.

The analysis of English postlexical place assimilation can be illustrated in the table (24). In addition to the convention described along with (20), the following notations are employed: a symbol {} indicates a reduced segment; capital letter indicates a lengthened segment.)

(24) late call --> [ley{t} Kɔl]

	candidates	Pres(mnr (-cont))	Pres (pl(onset))	Weak	Pres (pl(cor˺))	Pres (pl(coda))
☞	ley{t} Kɔl			*	*	*
	ley{t} kɔl	*!		*	*	*
	leyT {k}ɔl		*!	*		
	leyt {k}ɔl	*!	*	*		
	ley{t} {k}ɔl	**!	*		*	*
	leyT Kɔl			**!		
	leyt kɔl			**!		

The correct output *ley{t} Kɔl* violates only lower-ranked constraints: it violates the Weakening once due to the preservation of the onset gesture, i.e. velar. All the other candidates violate either higher-ranked constraints or Weakening twice. When the target segment in the optimal output is reduced enough, its perceptual loss will result. (See section 4.4.2 for the detailed analysis of gradiency in assimilation.) Again, a constraint preserving manner cues, i.e. Pres(mnr(-cont)), has the effect of compensatory lengthening, i.e. lengthening of silence from the trigger stop. (See the relevant discussion in section 4.2.2 for the role of the manner preservation constraints in compensatory lengthening effects.)

The alveolar coda reduction is captured in the same way. Its analysis can be illustrated by the table in (25):

(25) cat --> [kæ{t}]

	Candidates	Pres (pl(lab˺))	Weak	Pres (pl(cor˺))	Pres (pl(coda))
☞	kæ{t}			*	*
	kæt		*!		

Compare the table (25) and the following table showing the analysis of the labial coda:

(26) cap --> [kæp] *[kæ{p}]

Candidates	Pres (pl(lab˺))	Weak	Pres (pl(cor˺))	Pres (pl(coda))
☞ kæp		*		*
kæ{p}	*!			

Notice that the ranking of Pres(lab˺) over Pres(cor˺) explains the asymmetry between coronals and labials in coda reduction. In the above analyses, the coda glottalization, which can be separable from the coda reduction, is ignored. For the discussion about glottal reinforcement and its influence onto coda reduction (and place assimilation), see the discussion of Malay place assimilation in section 2.1. Also, in this section we did not discuss gradiency and optionality which can be observed in English place assimilation. We will attempt to provide a formal analysis for them in section 4.2.2.

In the proposed analysis, English postlexical place assimilation is captured by the relative ranking of general constraints which also govern the alveolar coda reduction. Thus, the fact that the two processes have the common target, i.e. an alveolar stop, is not an accident in the present analysis.

4.3.3 KOREAN

As described in Chapter Two and Three, Korean coronals assimilate in place to the following labials and velars, and in addition, labials assimilate in place only to velars:

(27) Korean consonant place assimilation[5]

a. /mit+ko/ --> [mikko]

'believe' 'and'

b. /cinan+pam/ --> [cinampam]

'last' 'night'

c. /ip+ko/ --> [ikko]

'wear' 'and'

but,

d. /ip+ta/ --> [ipta] *[itta]

'wear' + Sentence Ender

e. /ik+ta/ --> [ikta] *[itta]

'ripe' + Sentence Ender

f. /kuk+pota/ --> [kukpota] *[kuppota]

'(more) than' 'soup'

It has been assumed in the literature (Kim-Renaud 1974; Cho 1990 among others) that Korean place assimilation is optional, and it applies in casual speech. Confirming this assumption, the results reported in Chapter Three additionally show that the labial reduction giving rise to place assimilation is basically partial and it can apply across word boundaries (28) but not in the prepausal position (29).

(28) Across word boundaries

a. /ip kalita/ --> [ik kalita]

mouth hide

'(Somebody) hides his/her mouth'

---

[5] As in Chapter Two, broad phonetic transcriptions are employed for these Korean examples.

b. /cip kuhata/ --> [cik kuhata]

house get

'(Somebody) gets a house'

(29) Prepausal position

a. /ip/ --> [ip] *[i{p}] 'mouth'

b. /cip/--> [cip] *[ci{p}] 'house'

Thus, we assume that Korean place assimilation is a gradient postlexical process which result from the gestural reduction of coronals before noncoronals and labials before velars. To deal with the Korean data, a general constraint for preserving codas is divided into more specific constraints:

(30) Preservation of codas (New)

Pres(pl(__%)) >> Pres(pl(__C))

[% denotes a pause; Preservation of perceptual cues for a prepausal coda is more highly ranked than that for a coda followed by another consonant]

As shown in (31), prepausal unreleased coda consonant (C_1) can still maintain place cues in the transitions of the preceding vowel (V_1), whereas place cues in the vowel transition (V_2) for preconsonantal unreleased coda (C_2) may be obscured by the influence from the following consonant (C_3).

(31)

a. V_1C_1%

b. $V_2C_2C_3$

Thus, the ranking (30) can fall out from the acoustic fact that a coda followed by another consonant have acoustically weaker place cues due to the overlap with C_2 than a prepausal coda.

The ranking of complete set of constraints which are proposed for Korean place assimilation is in (32).

(32) Ranking for Korean place assimilation

Pres(mnr(-cont)), Pres(pl(onset)), Pres(pl(__%)), Pres(pl(dor˺)), Pres(pl(__cor)) >> **Weakening** >>

Pres(pl(lab˺)), Pres(pl(cor˺)), Pres(pl(__noncor)), Pres(pl(__C))

According to the proposed ranking for Korean place assimilation, both coronals and labials can be reduced in the preconsonantal coda position, since Pres(pl(lab˺)) and Pres(pl(cor˺)) are ranked below Weakening with Pres(pl(__C)). But, in addition to velars, labials would not be reduced before coronals since Pres(pl(__cor)) is ranked above Weakening. Thus, this relative ranking captures the asymmetry between coronals and labials in Korean place assimilation. Notice that all universal rankings within a set of constraints summarized in (17) are obeyed in (32). Based on the above ranking, we analyze /tk/ --> [{t}K] as shown in the following table:

(33) /it+ko/ --> [i{t} Ko]

	Candidates	Pres (mnr(-cont))	Pres (pl(onset))	Weak	Pres (pl(__C))	Pres (pl(cor˺))
	it ko			**!		
☞	i{t} Ko			*	*	*
	i{t} ko	*!		*	*	*
	it {k}o	*!	*	*		
	iT {k}o		*!	*		
	i{t} {k}o	*!	*		*	*

Notice that the correct output *i{t} Ko* violates only lower-ranked constraints. As in the analysis of English place assimilation, when the target segment in the optimal output is reduced enough, its perceptual loss will result. (See section 4.4.2 for the detailed analysis of gradiency in assimilation.) The analysis of the case in which coronals assimilate in place to labials will be subject to the same mechanism.

The analysis of the case in which labials assimilate in place to a following velar can be illustrated by the following table:

(34) /ip+ko/ --> [i{p} Ko]

	Candidates	Pres (pl(onset))	Weak	Pres (pl(__C))	Pres(pl (__noncor))	Pres (pl(lab˺))
	ip ko		**!			
☞	i{p} Ko		*	*	*	*
	iP {k}o	*!	*			

Notice that the labial before a velar needs to be reduced to obey Weakening; this reduction violates only constraints which are ranked below Weakening. In contrast, the other two candidates violate either higher-ranked constraints or Weakening twice.

Now, we are in a position to consider cases in which place assimilation does not apply. The following table illustrates how labials do not reduce before coronals:

(35) /ip+ta/ --> [ipta]

	Candidates	Pres (pl(onset))	Pres (pl(__cor))	Weak	Pres (pl(lab˺))
☞	ipta			**	
	i{p} Ta		*!	*	*
	iP {t}a	*!		*	

This analysis captures the fact, confirmed in Chapter Three, that labials do not reduce before coronals; thus, they cannot be targeted in place assimilation. Notice that the high-ranking of the constraint Pres(pl(__cor)) over Weakening is critical in preventing reduction of the labial before a coronal. The case in which velars do not reduce before coronals will be subject to the same mechanism; thus, we omit the table for its analysis. Instead, we show how velars do not reduce before labials in the following table:

(36) /kuk+pota/ --> [kuk pota]

Candidates	Pres (pl(onset))	Pres (pl(dor˺))	Weak	Pres (pl(__C))
☞ kuk pota			**	
ku{k} Pota		*!	*	*
kuK {p}ota	*!		*	

Since the Pres(pl(dorñ)) is ranked above the Weakening, the reduction of a velar, which will satisfy the Weakening but will violate a higher-ranked Pres(pl(dor˺)), can never occur.

Finally, the following table illustrates the analysis of the prepausal coda:

(37) /ip/ --> [ip]

Candidates	Pres (pl(__%))	Weak	Pres (pl(lab˺))	Pres (pl(__C))
☞ ip		*		
i{p}	*!		*	

According to the ranking for Korean place assimilation (32), labials can be reduced before a consonant, since both Pres(pl(lab˺)) and Pres(pl(__C)) are ranked below Weakening. However, due to a higher-ranked Pres(pl(__%)) which requires preservation of a prepausal coda, the output with a reduced prepausal labial is not an optimal one. This analysis captures the fact that Korean coda consonants do not reduce in the prepausal position.

In conclusion, we have shown an analysis for Korean place assimilation by proposing a single ranking for constraints in (32) which obeys all universal rankings within each set of constraints summarized in (17).

4.4 *DISCUSSION*

4.4.1 *MORE ABOUT PRESERVATION CONSTRAINTS*

We have analyzed attested patterns of place assimilation by proposing two conflicting groups of constraints, Weakening and Preservation. Preservation constraints are more complicated in several respects than Weakening constraints. Preservation constraints can be divided into two types depending on which perceptual cue, place or manner, needs to be preserved. They are further classified into several sets by segmental classes. Each such set is given a universal ranking depending on acoustic hierarchies. Due to these complications, the discussion of Preservation constraints was somewhat simplified in the preceding sections. Let us discuss the Preservation constraints in more detail; then, we will discuss their universal rankings.

The general format of Preservation constraints in (4) indicates that a constraint Pres(X(Y)) is satisfied if perceptual cues for X, i.e. place or manner of articulation, of Y, i.e. a certain segmental class, are preserved. For instance, Pres(pl(stop)) requires preservation of place cues of stops. However, Preservation constraints must not be understood as requiring preservation of **specific** perceptual cues per se. Rather, they require preservation of information (about place or manner-of-articulation of a certain segmental class) that those cues typically carry. For instance, the Pres(pl(stop)) does not require preservation of all stop place cues per se (e.g. release burst, and formant transitions of vowels preceding and following the stop); rather it only requires preservation of the information about point-of-articulation of a stop which all stop cues typically carry. Thus, when the output involves different place cues from the input, the output may satisfy a Pres(pl(X)) if the place cues of the output carry as much place information as those of the input. Most phonological processes which change manner of the input but maintain its place belong to this category; e.g. Obolo consonant lenition (Faraclas 1982:73-4) where Vp+V --> VwV. Notice that in Obolo consonant lenition, a place cue in the burst is replaced by that in the resonance formants. Nonetheless, the Pres(pl(stop)) is satisfied under the assumption that resonance formants carry sufficient place information to recover the place of articulation.

In summary, Preservation constraints must be evaluated on the amount of perceptual information which identifies place or manner of the input. Thus, whether a specific perceptual cue survives will not necessarily affect the evaluation of Preservation constraints.

Then, Preservation constraints can form a continuum, since the amount of perceptual information must be continuous. Let us consider one possbile such continuum shown in (38), taking the Pres(pl(unrel stop)) which requires preservation of perceptual cues of an unreleased stop:

(38) ... Pres(pl(unrel stop + 2)), Pres(pl(unrel stop + 1)), Pres(pl(unrel stop)), Pres(pl(unrel stop - 1)), Pres(pl(unrel stop - 2)) ...

Here the numbers "plussed" or "minused" from 'unrel stop' are employed to indicate the amount of perceptual information which is greater or lesser than that of the information which perceptual cues for an unreleased stop typically carries. Then, under the assumption that a released stop includes more information about its place of articulation than a corresponding unreleased stop, a Preservation constraint which requires preservation of place cues of a released stop will be Pres(pl(unrel stop + α)) where α is bigger than 0.[6] Consequently, most Preservation constraints proposed in the preceding sections can be divided into more specific constraints. For instance, the Pres(pl(stop)) in the preceding sections has been considered only Pres(pl(unrel stop)): in its evaluation, unreleased stops which overlap with the following consonant satisfies this. However, as shown in (38), the Pres(pl(stop)) in the preceding sections is just one, i.e. Pres(pl(unrel stop)), of many constraints which preserve place cues of a stop.

We are now in a position to consider how to measure the amount of information that perceptual cues carry. In our proposal, the amount of perceptual

[6]As we mentioned in section 4.2.2.1, the release burst includes a prominent place cue for the stop; thus, the constraint preserving place cues for the released stop would be highly ranked, usually (probably, always) outranking Weakening constraints. This may account for the fact discussed by Kohler (1991) and Lamontagne (1993), among others, that released stops are less likely to undergo assimilation.

information is identified by acoustic salience. How to provide an exact measurement of acoustic salience is not known. Nonetheless, there are ways to compare sounds in terms of acoustic salience. For instance, if one sound has more cues than other sounds, the former will be considered an acoustically more salient sound than the latter. Also, if a sound has a more prominent cue than other sounds although they have the same cue, the former should be considered acoustically more salient sound than the latter. This is the strategy adopted by the present study in proposing acoustic hierarchies for universal rankings of Preservation constraints.

Thus far, we have discussed Preservation constraints, the explanation of which was somewhat simplified in the preceding sections. We would now like to clarify that universal rankings in the present study are proposed only for the ease of explanation. The universal ranking should not be understood as a separate device in our approach. They are simply the result of applying the Production Hypothesis to sets of Preservation constraints which involve segments under various segmental (or syllable) contexts. The universal ranking of Preservation constraints involving a certain set of segments is no more than placing each segment on the acoustic salience scale. If a certain segment has a very salient perceptual cue, falling high on the salience scale, then the constraint preserving its perceptual cues should take the corresponding high ranking. Thus, the universal ranking will automatically fall out from the Production Hypothesis and the acoustic hierarchy of segments.

4.4.2 Gradient Assimilation

As discussed above, many casual speech assimilations are gradient. Remnants of the target gesture have been often observed in English (Barry 1985, 1991; Browman and Goldstein 1990; Nolan 1992; and Byrd 1994) and in Korean (Ch. 3). Then, the question which needs to be answered is why the reduction of the target gesture is not complete in these languages. According to our mechanism, gestural reduction comes from the high-ranking Weakening constraint which requires the conservation of articulatory effort. Then, the output which displays no target gesture at all will best satisfy Weakening, since it can obtain the maximum conservation of articulatory effort. Thus, we need to find out what prevents the reduction from going all the way to zero output, that is, patterns of gradiency.

We claim that partial reduction must be the result of an attempt to preserve even remnants of the perceptual cues.[7] In the previous section, we showed that proposed Preservation constraints are actually a family of continuous constraints distinguished only by the amount of place-of-articulation information which is measured by acoustic salience. Recall that in (38), Pres(pl(unrel stop)) requires preservation of perceptual cues of an unreleased stop with maximum closure, we may plausibly assume that Pres(pl(unrel stop - 1)), Pres(pl(unrel stop - 2)), ... require preservation of perceptual cues of an unreleased stop with reduced closure: as the gesture reduces, its acoustic power weakens. More specifically, if Pres(pl(unrel stop - 100)) requires preservation of perceptual cues of an unreleased stop with zero closure, then Preservation(pl(unrel stop - X)), where $0 < X < 100$, requires preservation of perceptual cues of an unreleased stop with partially reduced closure. Based on the Production Hypothesis, we can provide the following ranking for these constraints.

(39)

Pres(pl(unrel stop)) >> Pres(pl(unrel stop - X)) >> Pres(pl(unrel stop - 100)),

where $0 < X < 100$.

We can also divide the Weakening constraint into the same type of continuous constraints distinguished only by the amount of articulatory effort. As shown in (40), articulatory effort can be viewed as ranging from 0 % to 100 %, unlike acoustic salience, which does not have logical maximum degree.

(40) Articulatory effort

0 % 10 % 20 % ... 80 % 90 % 100 %

|----------|----------|-------...-------|----------|---------|

Each point in (40) can be paired with a corresponding Weakening constraint, shown

[7] Thanks to Pat Keating for suggesting this possibility.

in (41). (The name of 'Weakening' constraints is replaced by 'Save' which suggests their motivation more precisely. This name ise adopted for the rest of this section.)

(41) Weakening constraints

Save(0 %) >> Save(1 %) >> Save(Y %) >> Save (100 %),

where 1 < Y < 100.

The ranking in (41) is based on the assumption that if the violation of a constraint is more serious than that of some other constraint, the former constraint must be more penalized than the latter. Specifically, the violation of Save(1 %) represents the case in which even a minimum of articulatory effort is not conserved, whereas that of Save(100 %) represents the case in which maximal articulatory effort is not conserved. Thus, if we consider the motivation of Weakening constraint, i.e. 'conserve as much articulatory effort as you can', the violation of Save(1 %) should be more serious than that of Save(100 %): in the former, no effort is conserved (that is, no articulation is implemented), whereas in the latter, maximum articulatory effort is not conserved (i.e. some percentage of articulatory effort can still be conserved).

How these subdivided Weakening constraints interact with Preservation constraints in (39) determine language-specific reduction patterns. Pres(pl(unrel stop)), Pres(pl(unrel stop - X)), and Pres(pl(unrel stop - 99)) conflict with Save(1 %), Save(Y %), and Save(100 %), respectively, where 0 < X < 99 and 1 < Y < 100. For example, if Pres(pl(unrel stop)) is satisfied, then Save(1 %) cannot be satisfied: only the output with full closure, with which even the minimum percentage of articulatory effort cannot be conserved, can satisfy Pres(pl(unrel stop)). The output with full closure, i.e. no reduction, can fall out from the ranking in which Pres(pl(unrel stop)) outranks Save(1 %):

(42) No reduction (full closure)

Pres(pl(unrel stop)) >> Save(1 %) ...

To satisfy the high-ranking Pres(pl(unrel stop)), all other lower-ranking constraints must be sacrificed; thus, their relative rankings are not crucial. Notice that as long as

Save(1 %) is outranked by Pres(pl(unrel stop)), all other Weakening constraints except Save(0 %) must also be outranked by Pres(pl(unrel stop)), since Save(1 %) always outranks the other Weakening constraints, as shown in (41).

If Save(1 %) outranks Pres(pl(unrel stop)), the output with full closure cannot be optimal; at least a minimum percentage of articulatory effort needs to be conserved:

(43) Reduction

Save(1 %) >> Pres(pl(unrel stop))...

If all Weakening constraint outranks their conflicting Preservation constraints, the output with complete reduction will be optimal:

(44) Complete reduction (No closure)

Save(1 %) >> Pres(pl(unrel stop)) >> Save(Y %) >> Pres(pl(unrel stop - X)) >> Save(100 %) >> Pres(pl(unrel stop - 99))

If only some high-ranked Weakening constraints outranks their conflicting Preservation constraints, then the output with partial reduction will be optimal:

(45) Partial reduction (Residual gesture)

Save(1 %) >> Pres(pl(unrel stop)) >> Pres(pl(unrel stop - X)) >> Save(Y %) >> Pres(pl(unrel stop - 99)) >> Save(100 %)

To satisfy the top-ranked Save(1 %), at least some reduction is necessary. But further reduction is blocked due to Pres(pl(unrel stop - X)) outranking its conflicting Save(Y %). Thus, the output with partial reduction will be the optimal output.

Finally, if all Weakening constraints are **unranked** with respect to their conflicting Preservation constraints, all kinds of outputs, ranging from zero to full closure, can be equally optimal:

(46) Optional, variant, reduction

Save(1 %), Pres(pl(unrel stop)) >> Pres(pl(unrel stop - X)), Save(Y %) >> Pres(pl(unrel stop - 99)), Save(100 %)

Notice that the number of violations are always identical, since all conflicting constraints are unranked with respect to each other. Either one of each pair of conflicting constraints is always violated. Thus, all kinds of outputs such as that with full closure and that with no closure will be equally optimal.[8]

Consequently, in addition to categorical and obligatory assimilation patterns, we can provide an explicit formal analysis for optional and gradient reduction patterns which can be observed in English and Korean place assimilation.

4.4.3 MOHANAN (1993)

Mohanan (1993) claims that crosslinguistically recurrent, but exceptionless, phonological patterns result from 'fulfulling nonabsolute (unmarked) universal distributional requirements'. Adopting a concept from the theory of dynamical systems, he considers such requirements 'universal attractors', whose fields of attraction are analogous to magnetic fields. Accordingly, patterns of place assimilation are viewed as fields of attraction which a distributional requirement on consonant clusters (47) and its conflicting force (48) are mainly responsible for:

(47) (Mohanan #24)

In the sequence

[+stop] [+cons]

the two consonants must share a single place node

(48) (Mohanan #37)

A dominant unit resists the forces that alter its properties.

---

[8]This treatment of 'optionality' has benefited from discussion with Katherine Crosswhite.

The distributional requirement (47) forces heterorganic clusters to give up one place specification. The choice between the two place specifications depends on a universal statement, e.g. (49), written in terms of dominance defined in (48).

(49) (Mohanan #39)

[-coronal], [-anterior], and [+back] are dominant.

According to (49), velars are most dominant since velars have all three dominant features. Thus, this explains why velars are least likely targets as well as most likely triggers in place assimilation.

Moreover, following Lindblom (1988), Mohanan suggests that there may be phonetic and functional motivations for place assimilation: place assimilation is the result of "the optimization of two competing requirements, namely, (i) the minimization of articulatory cost, and (ii) the maximization of discriminability." Thus, within his theory, (47) and (48) are conflicting phonological principles which are motivated by the following phonetic requirements:

(50) a. Minimize the number of articulatory gestures. (Mohanan #54a)

b. Maintain the phonetic distinctions that distinguish between different words. (Mohanan #55)

Thus, the present study follows Mohanan in the main issue (how to formalize variable, but constrained, patterns of place assimilation), and the basic assumption (patterns of place assimilation are the results of compromizing two conflicting demands, (i) minimization of articulatory effort, and (ii) maintenance of contrasts). However, in addition to relatively small improvements in the discussion of the data, e.g. gradient assimilation (Mohanan considered Korean and English place assimilation as categorical), there is an essential difference. The present study analyzes place assimilation by employing constraints independently motivated by articulatory and perceptual mechanisms, whereas Mohanan's analysis is primarily based on the attested patterns of place assimilation typology, employing an unanalyzed primitive, i.e. dominance. Thus, it seems that the present study improves an analysis of place assimilation in capturing the phonetic naturalness involved in place assimilation.

4.5 CONCLUSION

Let us evaluate the analysis of place assimilation proposed in the present Chapter, based on the following list of place assimilation facts discussed in Chapter One:

(51) (From Ch. 1 #8)

a. Language-specific variability

b. Implicational statements

c. Phonetic motivation underlying (b)

d. Gradiency (of gradient place assimilation)

First, the phonetic motivation for place assimilation is captured in the general format of universal ranking of Preservation constraints. As shown in (4), universal rankings of Preservation constraints depend on the acoustic hierarchy, since they are subject to the Production Hypothesis. Specific rankings of each set of Preservation constraints correspond to implicational statements on place assimilation. For instance, the implicational statements about target manner (Ch. 2 #54a) are the result of applying the ranking for target manner in (5).

In addition to these universal patterns, the proposed analysis captures language-specific variability by assuming language-specific interactions of the proposed sets of constraints. For instance, as shown in 4.3, the distinct patterns of place assimilation in Korean and English are the result of different interactions between the Weakening constraint and Preservation constraints. In the Preservation constraints requiring preservation of perceptual cues for place of articulation, preservation of coronals, labials, and velars are ranked in increasing order. This universal ranking is obeyed in both English and Korean. However, they are different in how the Preservation constraints interact with the Weakening constraint. In English, the Weakening constraint is ranked above the constraint preserving coronals but below the constraints preserving labials and velars. In contrast, in Korean, the

Weakening constraint is ranked above constraints preserving coronals and labials but below the constraint preserving velars. Thus, in both languages, coronals reduce--being targeted for place assimilation--and velars are preserved--resisting place assimilation. But only in Korean, not in English, do labials reduce, being targets of place assimilation. In summary, sets of phonetically based constraints and their internal rankings constitute the raw material of grammars, whereas the rankings of different sets of constraints constitute the language-particular elements.

Also, the present study captures the gradiency of gradient place assimilation by subdividing Weakening and Preservation constraints, as presented in section 4.4.2. Subdivided Weakening constraints are distinguished by the percentage of articulatory effort. Subdivided Preservation constraints are distinguished by the amount of perceptual information. If a Preservation constraint requiring the preservation of **some** perceptual information outranks its conflicting Weakening constraint, but the Preservation constraint requiring the preservation of **all** information is outranked by its conflicting Weakening constraint, a partially reduced output will be optimal, satisfying the higher-ranked constraints and, at the same time, failing to satisfy their conflicting lower-ranked constraints. The completely reduced output cannot be optimal, since it will violate a higher-ranked constraint requiring the preservation of some perceptual information. The output with full closure cannot be optimal, either. It will violate a higher-ranked Weakening constraint which is in conflict with the constraint requiring the preservation of all information. Thus, in this analysis, gradiency is the result of the attempt to preserve some, not all, perceptual information. Consequently, the present study captures all the crucial facts related to place assimilation in (51).

Let us finally consider how the present approach is different from the previous approaches. It seems that none of the previous approaches succeeded in capturing both language-specific variability and the phonetic naturalness which characterize place assimilation patterns. As discussed in section 1.2.2, some approaches (e.g. autosegmental phonology and coronal underspecification) are successful in providing an explicit formal analysis for language-specific patterns but fail to capture most implicational statements, not to mention the phonetic factors underlying them; on the other hand, some approaches (e.g. articulatory phonology) are very promising in capturing phonetic naturalness, but need to be elaborated to deal with language-specific variability. In the present study employing Optimality Theory, rerankability of constraints can easily deal with language-specific patterns of place assimilation. Moreover, the universal rankings of perceptually based constraints which are determined by the acoustic salience capture implicational statements on place assimilation and phonetic naturalness underlying them.

Most importantly, the present study is different from the previous approaches in proposing a formal mechanism which is not confined to place assimilation. In fact, we propose a mechanism for speech production in general. This general mechanism provides, indirectly, an explicit formal account for place assimilation which is assumed to obey principles governing speech production.

Appendix: Experimental Phrases

The relevant segmental sequences (e.g. ipko, ikko, ipto) are underlined.

I. Experiment One: Korean *pk*

a. [sɛlo san paci-lɨl ip-ko pata-e kas'əyo]
new buy pants-Acc wear-and sea-to went
I went to the sea wearing new pants.

b. [p^{h}alan i ip-kwa yep'ɨn cə k'oc^h-i əullyəyo]
blue this leaf-and pretty that flower-Subj match
These blue leaves match those pretty flowers well.

c. [apəci-lɨl hakkyo ipku-esə poas'ə yo]
father-Acc school entrance-Loc saw
I saw my father at the school entrance.

d. [cip-e ka-ko sipko p^{h}ikonhɛs'əyo]
home-Loc go-Con want-and was tired
I wanted to go home and was tired.

II. Experiment One: Korean *kk*

a. [sakwa-ka cal ik-ko is'əyo]
apple-Subj well ripe-Con exist
Apples are growing well.

b. [əce iik-kwa sonhɛ-lɨl kyesan hɛs'əyo]
yesterday gain-and loss-Acc count did
Yesterday, I counted gains and losses.

c. [ce ilɨm-ɨn oikku-yɛyo]
my name-Top proper name-to be
My name is Oikku.

d. [pap-i sik-ko is'əyo]
rice-Subj cool-Con exist
The rice is cooling down.

III. Experiment Three: Korean *pt*

a. [sɛlo san paci-lɨl ip-ko pata-e kas'əyo]
new buy pants-Acc wear-and sea-to went
I went to the sea wearing new pants.

b. [sɛlo san paci-lɨl ip-tolok putak hɛs'əyo]
new buy pants-Acc wear-and request
I asked (somebody) to wear new pants.

c. [pʰalan i ip-kwa yep'ɨn cə k'ocʰ-i əullyəyo]
blue this leaf-and pretty that flower-Subj match
These blue leaves match those pretty flowers well.

d. [pʰalan i ip-to yep'ɨn k'ocʰ-kwa əullyəyo]
blue this leaf-too pretty flower-Subj match
These blue leaves match pretty flowers well, too.

e. [apəci-lɨl hakk'yo ipku-esə poas'ə yo]
father-Acc school entrance-Loc saw
I saw my father at the school entrance.

f. [apəci-k'e iptaŋ-ɨl putak hɛs'əyo]
father-Dat join (a political party)-Acc request
I asked my father to participate in a political party.

g. [cip-e ka-ko sip-ko pʰikonhɛs'əyo]
home-Loc go-Con want-and was tired
I wanted to go home and was tired.

h. [cip-e ka-ko sip-tako piləs'əyo/
home-Loc go-Con want-Con beg
I asked (somebody) to let me go home.

IV. Experiment Four: Korean cross-word boundary *pk*

a. /yep'ɨn nolan ipʰ kukyəŋ hɛ pwayo/
pretty yellow leaf watch try
Try to see yellow leaf.

b. /pyəŋwən-esə ipkwan-ɨl cikyə pwas'əyo/
hospital -Loc placing in the coffin-Acc observed
I observed placing (a corpse) in the coffin in the hospital.

c. /op'a-ka yosɛ cip kuha-lə tanyəyo/
brother-Nom nowadays house seek-Pur go around
My brother is going around to look for a place to live.

d. /pihɛŋki-esə cip-kwa hakkyo-ka cakke poyəs'əyo/

airplane-from house-and school-Nom small looked

From the airplane, houses and school looked small.

e. /pap məkɨl t'ɛ ip kali-ko məkəs'əyo/

rice eat time mouth hide-and ate

While eating rice, I hid my mouth.

f. /pocokɛ-ka ipka-e poyəs'əyo/

dimple-Nom mouth edge-Loc seen

A dimple was seen at the edge of the mouth.

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