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The Status of the Lenis Stop Voicing Rule in Korean*

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Lenis Stop Voicing in Korean has been assumed to be a phonological rule. This paper attempts to evaluate the status of this rule according to the criteria suggested by Keating (1988, 1990) and Pierrehumbert (1990). Voicing of an intervocalic lenis stop was examined in different segmental and prosodic contexts as well as for different speech rates. The data show that the voicing of a lenis stop is not categorical but gradient and quantitative. This suggests that Lenis Stop Voicing is a phonetic rule. The phonetic characteristics of the Lenis Stop Voicing rule are interpreted using Browman and Goldstein's (1987) gestural analysis.

1. Introduction

Phonetic studies of Korean stops (Han & Weitzman, 1970, Kagaya, 1971, and Kim, 1965, etc.) have found that lenis stops or slightly aspirated stops in Korean become voiced intervocalically within a word. More recently, Cho (1990), Jun (1990a, b) and Silva (1989) have suggested that lenis stops are voiced intervocalically within a phonological phrase. Even though their ways of defining a phonological phrase differ from one another, they agree

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in that Lenis Stop Voicing occurs within a phonological phrase which is larger than a phonological word according to the prosodic hierarchy proposed by Selkirk (1980, 1986) and Nespor & Vogel (1986). Therefore, based on either phonetic studies or impressionistic studies, it has been assumed that the Lenis Stop Voicing rule is a phonological rule—in particular, a postlexical phonological rule (Ahn 1986).

However, recent phonetic studies suggest another possibility. Silva (1991) showed that lenis stops have different degrees of closure voicing and VOT duration depending on their prosodic environments and claimed that lenis stops have three acoustic realizations: voiceless lightly aspirated, voiceless unaspirated, and voiced unaspirated. Jun (1990a, b) also showed that the probability of voicing of a lenis stop depends on its position within the intonational structure of a sentence, which is affected by many factors in addition to the syntactic structure of the sentence, such as speech rate, the length of a sentence, and focus, etc. I found that, in general, lenis stops become voiced within an Accentual Phrase[1] but remain voiceless at the beginning of an Accentual Phrase.

This paper tries to evaluate the status of the Lenis Stop Voicing rule—that is, whether it is a phonological rule or a phonetic rule, based on the criteria suggested by Keating (1988, 1990) and Pierrehumbert (1990). The distinction between phonetic and phonological rules has recently discussed in the literature with a lot of debate. Kiparsky (1985) argues that postlexical rules which are feature changing are truly phonological and they apply categorically, while some postlexical rules which apply gradiently are phonetic implementation rules. However, he does not provide any specific mechanisms of phonetic implementation. Pierrehumbert (1990) and Keating (1990) agree that phonological rules are categorical and responsible for the qualitative contrasts, not gradient distinctions, in sound. Phonetic rules, on the other hand, are gradient/quantitative and are responsible for describing speech as a physical phenomenon, covering measurable properties of articulation, acoustics and audition. Pierrehumbert also suggested that phonetic rules are noncognitive and relatively inaccessible to introspection.

First, using data from Jun (in preparation), I will show that the Lenis Stop Voicing rule is sensitive to speech rate. Thirty-four sentences with a different structure were read three times by five speakers at three self-selected rates: fast, normal and slow. Based on the pitch tracks of sentences, the Accentual Phrases within an utterance were counted. To

[1] An Accentual Phrase is a phonological phrase determined by a tonal pattern within a sentence. An Accentual Phrase in Seoul dialect has a Low-High pattern, whereas that of Chonnam dialect has either a Low-High-Low or High-High-Low pattern depending on the laryngeal feature of the phrase initial segment: If the segment has either [+spread glottis] (=aspirated) or [+constricted glottis] (=tensed), the phrase has a H-H-L pattern, otherwise, L-H-L pattern. For more details, see Jun (1989, 1990b).

assess the speech rate of each speaker, the mean duration of a syllable is calculated by measuring a whole or part of sentences in each speech rate. Figure 1 shows the number of Accentual Phrases plotted against speech rate, showing each speaker's tendency. As seen from the figure, the speech rate is not the same across speakers. However, for each speaker, it is clearly shown that as the speech rate increases (i.e. the shorter the mean syllable duration), the number of Accentual Phrase decreases. Having fewer Accentual Phrases in an utterance means more cases of phrase medial lenis stops and, therefore, more cases of voiced lenis stops. That is, the faster the utterance, the more often the target lenis stops were voiced.[2]

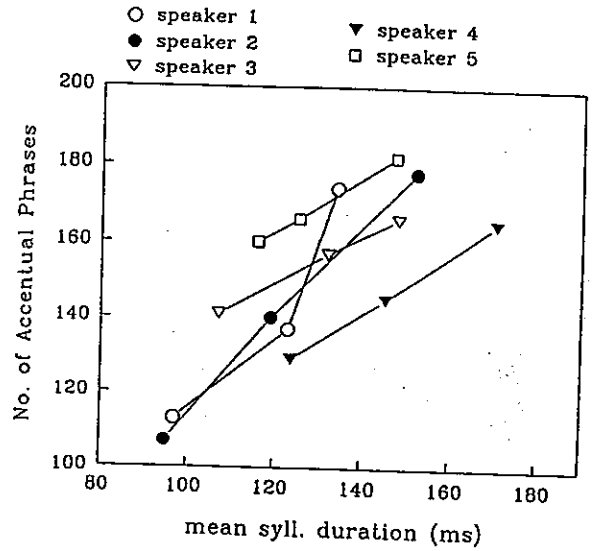

Figure 1. The number of Accentual Phrases against the mean duration of a syllable.

The following table shows the voicing status of a word-initial lenis stop at different speech rates. The voicing status of a word-initial lenis stop within a sentence was considered to show its change in voicing due to the change in Accentual Phrasing. There were 195 word-initial lenis stop tokens (65 words × 3 repetitions) for each rate. Each number is a sum of completely voiced and partially voiced tokens. Numbers preceding the parentheses are

[2] At fast rates, there were a few cases when even a lenis stop in an Accentual Phrase initial position, e.g. VP-initial lenis stop in a structure of Subj. NP + VP, became voiced.

based on audio waveform data; those in parentheses are based on Electroglottogram data.

Table 1. The number of voiced word initial lenis stop tokens depending on speech rates.

Subject \ Rate	Slow	Normal	Fast
1	23 (20)	51 (56)	78 (85)
2	18 (18)	51 (50)	108 (96)
3	13 (14)	19 (21)	40 (40)
4	33 (34)	46 (52)	77 (73)
5	16 (14)	37 (36)	50 (48)

Table 1 shows that, for each subject, the number of voiced lenis stop increases as speech rate increases. Therefore, it is clear that the Lenis Stop Voicing rule in Korean is sensitive to speech rate.

Next, acoustic data for lenis stops were gathered in different segmental contexts as well as in different prosodic contexts. A relevant set of data is selected from an ongoing study of vowel devoicing that I am conducting in collaboration with Mary Beckman (Jun and Beckman, forthcoming).

2. Method

Forty-five sets of sentences uttered by six speakers (three Seoul and three Chonnam, one female and two males for each dialect) were analyzed. Each set of sentences was a short dialogue, containing word-initial or word-medial lenis stops in different focusing positions, as shown below:

(i)	igɛ x ni?	'Is this **X**?'
(ii)	ɑni, tʃəgɛ x ja.	'No, THAT is x.'
(iii)	kirəm, igɛ y ni?	'Then, is this **Y**?'
(iv)	iŋ, kigɛ y ja.	'Yes, THAT is y.'

The underlined portions are focused words, and x or y is a word of $C_1V_1C_2V_2$. Thus, each word is produced Accentual-Phrase–initially [when x or y is focused as in (i) and (iii)], as well as Accentual-Phrase–medially

(when tʃəgɛ or kigɛ is focused as in (ii) and (iv)]. For five words, C_1 is a lenis stop (in **boldface** below) and C_2 is either a tense stop, an aspirated stop, a lenis stop, a lenis fricative [s], or a tense fricative [s'] as in (v).

(v) **t**uk'ɛ 'thickness', **k**ip^{h}i 'evasion', **k**utu 'shoes'
kisɑ 'news', **k**us'o (kut+so)[3] 'harden+ending'

Furthermore, for another five words, C_1 is either tense, aspirated, lenis stop, [s] or [s'] and C_2 is a lenis stop (underlined below) as in (vi).

(vi) t'upu 'tofu'[4], t^{h}uki 'venture', kutu 'shoes'
sikɟɛ 'a watch', s'itɑ 'to write'

(The vowel between the two consonants was always a high vowel because the corpus is from a study of vowel devoicing, which a pilot study showed to primarily affect high vowels.)

The portion of the utterance around each target lenis stop was displayed as a wide band spectrogram on the DSP Sona-Graph (model 5500), and the stop was examined for voicing. There were many cases where the voicing status of a lenis stop was not obvious or categorical. Rather, the degree of voicing was gradient. However, for the sake of presentation, I classified the cases into three categories: 'completely voiceless', when there is no vibration of vocal folds during the stop closure; 'partially voiced', when there is only one or two voicing pulses at the beginning or end of the stop closure; and 'completely voiced', when the voicing bar continues more than two pulses throughout the whole stop closure.

3. Results and Discussion

The results show that, in intervocalic position, word-initial lenis stops are almost always voiceless at the beginning of an Accentual Phrase, as predicted by earlier accounts. However, word-initial lenis stops in the middle of an Accentual Phrase, and even word-medial lenis stops, are not always voiced. Rather, the voicing of a word-medial or a word-initial but Accentual-Phrase–medial lenis stop largely depends on the quality of neighboring segments. I will discuss each of these latter cases in turn.

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[3] Due to Spirantization and tensing, /t/+/s/ is produced as a tense fricative, [s']. See Jun and Oh (1992) for spectrographic analysis and Sawashima et al. (1980) for glottal time curves.

[4] This is a non-standard but still acceptable pronunciation. The standard pronunciation is [tupu].

3.1. Word-Medial Lenis Stops

The word-medial lenis stops were voiceless far more often than earlier accounts predict. This may be because they are following a high vowel which is likely to be devoiced adjacent to a voiceless consonant. Moreover, the stops tend to be voiceless more often when the consonant preceding the high vowel (that is, C_1) is a lenis or tense fricative, ([s] or [s']), or an aspirated stop than when it is a lenis or tense stop.

The voicing status of the word-medial lenis stop (C_2) in the context of different C_1 types is shown in Table 2. Since voicing of word-medial lenis stops does not show any significantly different pattern in terms of whether the word containing it is in Accentual-Phrase-initial or medial position, the following table shows the number of tokens combined across both focus positions, thus 120 tokens for each C_1 (20 tokens for each speaker).[5]

Table 2. The voicing status of the word-medial lenis stop (C_2) in the context of different C_1 types.

C_1 \ C_2	Completely Voiceless	Partially Voiced	Voiced
Lenis fricative	87	6	26
Tense fricative	71	26	23
Aspirated stop	69	7	44
Lenis stop	9	19	90
Tense stop	6	4	110

As shown in Table 2, the voicing status of word-medial lenis stops changes depending on C_1 types. From the vowel devoicing experiment, it was found that the order of C_1 types affecting the degree of vowel devoicing was the same as that affecting the degree of voicelessness of a lenis stop. This suggests that the voicing status of a lenis stop is influenced by that of the neighboring vowel as well as that of the non-adjacent consonant.

3.2. Word-Initial Lenis Stops

When a word-initial lenis stop is in the middle of an Accentual Phrase as in (ii) and (iv) above (repeated below), we might expect it to behave as if it were a word-medial lenis stop following a syllable beginning with another lenis stop, (the [g] in bold below), and thus it would be voiced quite often as seen in Table 1 for truly word-medial lenis stops when the C_1 was also a lenis stop. (90 voiced tokens out of 120.)

(ii) ɑni, tʃəgɛ x ja. 'No, THAT is x.'

(iv) iŋ, kigɛ y ja. 'Yes, THAT is y.'

The results show that about 70% (196 tokens out of 281) of the word-initial but Accentual Phrase–medial lenis stop is voiced; this was a little smaller than the case of word-medial lenis stop with C_1 being a lenis stop, which showed 76% of voicing (90 tokens out of 120). The different propensities to voice was moderately significant ($\chi^2 = 7.87$, df=2, $p<.02$). The word-initial but Accentual Phrase–medial lenis stop might be voiced less often because the lenis stop is in word-initial position. This is a plausible explanation because it is shown in Jun (1990a) that the duration of VOT in [p^h] was significantly longer word initially than word medially. Or it could be voiced less often because the lenis stop is always followed by a high vowel which in turn is more likely to be devoiced due to the following voiceless consonant (C_2). By contrast, the word-medial lenis stops are followed by all kinds of vowels (V_2 = [ɛ, ɑ, u, i]) some of which would have less chance of devoicing because they are non-high, and all of which are less likely to be devoiced because the immediately following consonant is a voiced sonorant, [j] or [n], (due to the context of the carrier sentence). The latter explanation also looks reasonable if we consider that the frequency of voicing differs depending on the type of C_2 as shown in Table 3.[6]

Table 3 shows the status of the word-initial but Accentual-Phrase-medial lenis stop in the context of different C_2 types. There are generally total 60 tokens for each C_2; Tokens produced with wrong accentual phrasings were not included.

[5] There were two missing values in a Lenis stop-V-Lenis stop-V case.

[6] Since word-initial lenis stops do not have the same segmental contexts as word-medial lenis stops in our data, I cannot decide at this moment which factor is stronger in causing the word-initial lenis stop to be voiceless more often.

Table 3. The voicing status of the word-initial but Accentual-Phrase–medial lenis stop (C_1) in the context of different C_2.

C_2 \ C_1	Completely Voiceless	Partially Voiced	Voiced
Tense stop	17	10	30
Tense fricative	16	5	33
Aspirated stop	11	7	39
Lenis stop	12	2	42
Lenis fricative	2	3	52
Total	58	27	196

As shown in Table 3, word-initial lenis stops are voiceless more often when C_2 is tense consonants than it is lax or lenis consonants. Again, this order of C_2 affecting the voicelessness of lenis stop was found to be the same as that affecting vowel devoicing.

It is interesting to note, however, that the order of the non-adjacent consonant affecting the voicing of a lenis stop is not the same by the position of the lenis stop relative to the non-adjacent consonant. But, in both cases, it is clear that the voicing of the lenis stop changes depending on the type of the non-adjacent consonant.

3.3. Non-high Vowel and Lenis Stop C_1 by Lenis Stop C_2

As we have seen so far, the degree of voicing of a lenis stop changes depending on the type of the non-adjacent consonant. However, since the lenis stop is always followed or preceded by a high vowel which is likely to be devoiced, one might wonder if the voicing status of a lenis stop varies just because the intervening vowel is devoiced. Before I discuss the relationship between the vowel devoicing and the voicing of a lenis stop, I will show that the voicing status of a lenis stop still varies even after a fully voiced non-high vowel. To show this, I examined a context where a lenis stop is following a non-high vowel and the non-adjacent consonant is also a lenis stop to avoid vowel devoicing as much as possible. That is, the test word, *kutu* 'shoes', was examined in a carrier sentence(i.e., *igɛ kutuni ?)* in both Accentual Phrasings. The voicing of lenis stops, /k/ and /t/, and voicing of the intervening vowel were examined. There were 10 tokens for each speaker. The following tables show the status of voicing in three categories for the initial three segments of *kutu* for six subjects. Subject 1, 2, and 3 are Seoul speakers and subject 4, 5, and 6 are Chonnam speakers. 'Vl' refers to a 'completely voiceless' token, 'I' refers to an 'incompletely voiceless' token (i.e., when there were less than three pulses for a lenis stop and when the vowel has no formant structure and the duration of voicing is shorter than 30 milliseconds.), and 'Vd' refers to a 'voiced' token. Table 4 shows a case when the test word is uttered in an Accentual-Phrase-initial position and Table 5 shows the same word uttered in an Accentual-Phrase-medial position.

Table 4. The voicing status of the initial three segments in *kutu* in Accentual-Phrase-initial position, following a mid vowel [ɛ]

	/k/			/u/			/t/		
Subj.	Vl	I	Vd	Vl	I	Vd	Vl	I	Vd
1	10	0	0	1	1	8	1	0	9
2	10	0	0	0	0	10	0	4	6
3	10	0	0	1	5	4	2	0	8
4	10	0	0	0	3	7	0	1	9
5	10	0	0	0	0	10	0	2	8
6	10	0	0	0	6	4	0	1	9

Table 5. The voicing status of the initial three segments in *kutu* in Accentual-Phrase-medial position, following a mid vowel [ɛ]

	/k/			/u/			/t/		
Subj.	Vl	I	Vd	Vl	I	Vd	Vl	I	Vd
1	0	1	9	0	0	10	1	0	9
2	4	0	3	0	0	10	3	5	2
3	5	1	4	0	3	7	2	3	5
4	0	0	9	0	0	10	1	1	7
5	0	2	8	0	0	10	0	0	10
6	1	0	9	0	0	10	0	2	8

As seen from these tables, a word-initial and Accentual-Phrase–initial lenis stop, /k/, is always voiceless and the following high vowel is devoiced more often (Table 4) than the high vowel following a word-initial but Accentual-Phrase–medial lenis stop, /k/ (Table 5). However, the word-initial but Accentual-Phrase–medial lenis stop shows a similar degree of voicing to

that of word-medial lenis stops, even though the former is following a mid vowel and the latter a high vowel. The word-medial lenis stop, /t/, in Table 5 still shows some degree of voicelessness even though the preceding high vowel is mostly fully voiced. Thus, it is clear that the degree of voicing of lenis stops varies even after a fully voiced vowel. It is also shown that the degree of voicing of a lenis stop varies in the same segmental contexts and in the same prosodic position, even though there is a tendency to become voiced more often in word-medial than in word-initial positions, and voiced more often in phrase-medial than in phrase-initial positions. These results indicate that voicing of an intervocalic lenis stop within an Accentual Phrase is gradient and quantitative, suggesting that the Lenis Stop Voicing rule in Korean is a phonetic rule.

3.4. Phonetic Representation

The claim that the Lenis Stop Voicing rule is a phonetic rule can be supported by a vowel devoicing phenomena in Korean with a consideration of different glottal width for different consonant types. According to Kagaya (1974), aspirated stops in Korean have a large glottal opening with a peak around oral release, thus having long voice onset time (VOT). Tense stops in Korean have very small glottal opening and are tightly closed even before oral release. Lenis stops, on the other hand, have two patterns of glottal opening: a large opening (but smaller than that of aspirated stops) word initially but no opening word medially in an intervocalic position. From the preliminary experiment of vowel devoicing (Jun and Beckman, forthcoming), it was found that a high vowel becomes devoiced more often than a non-high vowel next to a voiceless consonant. Furthermore, a high vowel is devoiced more often when the preceding consonant has a larger glottal width like fricatives or an aspirated stop. From this result, we can speculate that high vowels which are intrinsically very short and therefore have a very short duration of vibration can be easily devoiced when the adjacent consonant has a large glottal opening. This can be represented using a phonetic model of coarticulation suggested by Browman and Goldstein (1987).

In Browman and Goldstein's model, utterances are represented as gestural score. Gestures are invariant but inherently spatiotemporal. Thus, gestures in the different articulatory tiers can be overlapping without perturbing each other's trajectories but even partial overlap of gestures in the same articulatory tier can lead to blending of the observed output characteristics of the two gestures. The evidence of gestural overlap analysis can be shown in Munhall and Löfqvist (1992). They looked at the glottal width in the sequence *kiss Ted*. In slow rates, there were two glottal opening peaks for [s] and [t] in the glottal width trace, But at normal rates, the two peaks are no longer clearly separated and at even faster rates, the two opening gestures blended so much together that they form one big peak.

Therefore, voicing of a lenis stop in an intervocalic position within an Accentual Phrase can be explained by involving not only the blending of closely phased voicing gestures but also the reduction of gestural amplitude of the glottal opening gesture responsible for the voicelessness. In other words, if the magnitude of the abduction gesture were slightly reduced, the critical value of vocal-fold separation for devoicing might never be reached.[7] On the other hand, the gestural score and blending account would predict that a lenis stop at an Accentual Phrase–initial position, having a somewhat large glottal opening, would possibly make the following high vowel devoiced by overlapping with the vowel's glottal gesture. Data in Table 4 and 5 show the interaction of a lenis stop voicing with an Accentual Phrasing.

Furthermore, this model can explain why the frequencies of the voicing of the word-medial lenis stop differ depending on the different type of the non-adjacent consonant (seen from Table 2) and why the intervening high vowels are devoiced more often next to fricatives or aspirated stops. That is, when the glottal opening gesture of a word-initial consonant is large as in an aspirated consonant and the glottal closing gesture of the following vowel is short and weak, the consonant's glottal opening gesture can blend so much with the glottal gesture of the following vowel that it can merge with the glottal opening gesture of the lenis stop following the vowel, creating a devoiced vowel and possibly a voiceless lenis stop. However, when the word-initial consonant is a fortis or tense stop (i.e. small glottal opening gesture), a high vowel following the consonant is less likely devoiced and lenis stops following the vowel are mostly voiced as seen from Table 2.

But, as we have seen in Table 3, when the lenis stop is at word-initial, the lenis stop is voiceless more often when the following non-adjacent consonant is more tense, thus not necessarily having a wider glottal opening. This may indicate that the glottal gesture of a segment is sensitive to the peak of the glottal opening gesture relative to the oral release. Or, the glottal opening gesture can be influenced by tension in vocal folds. Further research may need to clarify this relationship.

Finally, the Lenis Stop Voicing rule in Korean is not cognitive and is inaccessible to introspection. Naive native speakers of Korean cannot perceive voicing of a lenis stop and have a hard time producing a voiced stop intentionally. This again supports the claim that the Lenis Stop Voicing rule in Korean is a phonetic rule.

[7] A similar result is found in Japanese data. See Hirose et al. 1985.

4. Conclusion

The Lenis Stop Voicing rule in Korean has been assumed to be a phonological rule with their domain being a phonological phrase (Cho 1990, Jun 1990a, 1990b, Kang 1990, and Silva 1989). However, recent phonetic studies (Jun 1990a and Silva 1991) suggest another possibility. These studies showed that the voicing of lenis stops varies depending on speech rates or their position relative to the prosodic structure.

In this paper, I have attempted to evaluate the status of the Lenis Stop Voicing rule based on data from Jun (in preparation) and Jun and Beckman (forthcoming). Using data from Jun (in preparation), it is shown that the Lenis Stop Voicing rule is sensitive to speech rate; The faster the rate, the more an intervocalic lenis stop become voiced. Next, using data selected from Jun and Beckman (forthcoming), voicing of intervocalic lenis stops was examined in different segmental contexts in addition to different prosodic contexts. The intervocalic lenis stops were almost always voiceless at the beginning of an Accentual Phrase as earlier studies predicted. However, even though there is a tendency for an intervocalic lenis stop to become voiced more often in word-medial than in word-initial positions, and more often in phrase-medial than in phrase-initial positions, the data for the lenis stop in different segmental contexts show that the voicing of an intervocalic lenis stop is not categorical but gradient and quantitative. The gradient and quantitative characteristics of lenis stop voicing depending on speech rate and segmental contexts suggest that the Lenis Stop Voicing rule in Korean is not a phonological rule but a phonetic rule according to the criteria suggested by Keating (1988, 1990) and Pierrehumbert (1990). The phonetic characteristics of the Lenis Stop Voicing rule can be interpreted as blending and reduction of glottal opening gestures using Browman and Goldstein's (1987) gestural score model of phonetic representation.

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Sonority-based Conditions on the OCP: Evidence from Korean and Other Languages*

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The focus of this paper is an investigation of sonority in relation to the Obligatory Contour Principle (Leben 1973, Goldsmith 1976, and McCarthy 1986) observed in the Korean cooccurrence restrictions. On the assumption that the OCP is a universal principle, I will propose that the scope of the OCP can be parameterized by sonority-related features and articulator features along which particular conditions on the OCP can vary on a language-particular basis. As the justification for such a revised OCP, the OCP constraints in Semitic (McCarthy 1991), Russian (Padgett 1991), and Takelma (Goodman 1992) will be demonstrated to be well captured by the revised OCP.

1. Introduction

The scope of the Obligatory Contour Principle (henceforth, the OCP), according to which adjacent identical elements are not allowed to occur at the melodic level (McCarthy 1986: 208), has been extended from tonal phenomena (Leben 1973) to antigemination (McCarthy 1986) and dissimilation effects (Yip 1988) in nontonal phonology. Generalized in this way, the OCP predicts that identical adjacent elements are ruled out, merged into one, or dissimilated in order to avoid violating the OCP:

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