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1. Introduction

This study deals with the substance and formal nature of consonant geminates and their behavior within current Optimality Theory (McCarthy and Prince 1993, Prince and Smolensky 1993). It has been shown that geminates frequently behave exceptionally in two ways, Integrity and Inalterability (Kenstowicz and Pyle 1973, Guerssel 1977, 1978, Schein and Steriade 1986, Hayes 1986, Cho and Inkelas 1993).

(1) a. Integrity: Insofar as they constitute two segments, long segments can not be split by rules of epenthesis.
b. Inalterability: Long segments often resist the application of rules that a priori would be expected to apply to them.

(Hayes 1986: 321)

To account for these exceptional behaviors, attention has focused on representational properties employing doubly-linked structures of geminates that distinguish them from singletons. Accordingly, these special behaviors of geminates have been proposed to result from the unique branching geometry of geminates.

In this paper, however, contrary to previous accounts, I propose that the first half of the geminates (i.e. coda) is phonologically underspecified; only the onset is specified for features. Later, the phonetic component of the grammar interprets the underspecified coda and the onset geminate sequence as having the same features as the onset. That is, the coda gains its featural value from its onset neighbor later in the phonetic component[1] (cf. Cohn 1990, Heiberg in preparation, Keating 1988). To illustrate how the current assumption works within the perspective of Optimality Theory, I will present evidence from Persian coda weakening and Klingenheben's Law in Hausa.

The paper is organized as follows. Section 2 provides background information. Section 3 analyzes Persian v-->w weakening in the coda and Klingenheben's Law in Hausa. Section 4 summarizes the discussion of the paper.

2. Background Information

2.1 Phonological Representation of Geminates

In this paper, I adopt two-root representation for the geminates along the lines of Selkirk (1990), with two crucial differences. First, unlike Selkirk (1990) and McCarthy (1988), the root node is not constituted of specifications for the consonantal and sonorant features. Second, geminates are not doubly-linked, but rather the first half of the geminates is underspecified (and thus, not linked). Accordingly, the representation of the consonant geminates will be expressed as in (2).

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[1]I assume that intial and final geminates have also the same structure as medial geminates. That is, the first half of the geminates is underspecified and moraic.

(2) The Representation of Consonant Geminate

```
     σ              σ
    / \            / \
      μ            /
       \          /
        Rt      Rt
                 |
                PLACE
```

The first half of the geminate is represented as nothing more than a bare root node, which will be interpreted as the same features (e.g. PLACE) with the following onset by phonetics.

2.2 Background in Optimality Theory

Optimality Theory focuses not on the step by step derivation but on the constraints that underlie phonological changes. The constraints are simple and independently motivated which are present universally in all grammars. The goal here will be to achieve generality from simple constraints in different relations to each other. Optimality theory makes it possible to capture this generality through the interaction mechanism of phonological constraints. This mechanism makes use of differences in the ranking of the set of constraints in individual grammars. These constraints are violable, but violation is minimal. The notion of minimal violation is defined in terms of the ranking (cf. Prince and Smolensky 1993).

Optimality Theory abolishes phonological rules and other derivational notions. Instead it replaces them with the functions of Gen. and Eval.. Gen is a generative function which takes an input representation and returns an infinitely large set of possible output forms, or candidates.[2] Finally, Eval. procedure analyzes the optimal candidate in terms of a hierarchy of constraints. With this background, let us now consider Persian v--->w weakening in the coda and Klingenheben's Law in Hausa which weakened (i.e. sonorized) coda obstruents.

3. Geminate Inalterability in Persian and Hausa

3.1 Persian Coda Weakening

In Persian, in general, /v/ becomes /w/ whenever it occurs in syllable final position (3a). However, the syllable final /v/ fails to become /w/ whenever it forms the first half of a geminate (3b) (Hayes 1986).

(3) a. non-geminate coda

/nov-ru:z/	[nowru:z]	\`new day'
/bo-ræv[3]/	[borow]	\`go!'
/jËæv/	[jËow]	\`jow'
/pa:-dæv/	[pa:dow]	\`gofer'
/be-sËenæv/	[besËenow]	\`listen!'

[2]For the characteristics of Gen, see Prince and Smolensky 1993.

[3]Additionally, /æ/ becomes /o/ whenever it precedes /w/. However, in this paper, we will not discuss this matter.

b. geminate coda

/ævvæl/	[ævvæl]	`first'
/qolovv/	[qolovv]	`exaggeration'
/morovvæt/	[morovvæt]	`generosity'

To explain the geminate inalterability in Persian v--->w, Hayes (1986) proposes the following rule as shown in (4).

(4) Persian v--->w

```
                 σ
                / \
               V   C
               |   |
  v--->w      [ ] ___
```

The rule (4) indicates that /v/ is converted to /w/ when it is associated with the coda position after a short vowel. Geminates (3b) do not satisfy the structural description of the rule (4), because geminates will have a branching geometry (i.e.

```
C   C).
 \ /
  v
```

In other words, the associations of the /v/ melody exceed those permitted by the Linking Constraint (Hayes 1986)[4]. Thus, /v/ fails to become /w/ in geminate consonant clusters by the doubly-linked structure of itself.

However, the so-called Linking Structure approaches are too strong and have been criticized by many researchers (Goldsmith 1990, Selkirk 1990, Scobbie 1992, Cho and Inkelas 1993, among others). Geminates are not always inalterable or inseparable. In some cases, entire geminate or part of the geminate can be alterable (e.g. palatalization in Hausa and Luganda). Geminates can also be splittable by epenthesis (e.g. Marshallese). Considering these facts, I will account for the geminate inalterability effect taking current Optimality Theory framework together with underspecified representation of geminates, instead of the too powerful Linking Structure approach of geminates.

I now introduce constraints that are relevant to the treatment of Persian data, and show how the geminate inalterability effect is analyzed.[5]

(5) Constraints Set for Persian

a. *μw[-son]: Moraic coda must not be obstruents.
b. FILLseg: Segments (C or V) are filled with features.
c. PARSEseg: Segments (C or V) must be licensed by a higher prosodic unit.
d. PARSEfeat: Features must be licensed by a higher prosodic unit.
e. FILLfeat: Every root node must dominate a feature specification.
f. *PLACE: A Place node must not be specified in a coda.

The motivations for the constraints and the ranking are as follows. First, the constraint *μw[-son], motivated from onset/coda licensing asymmetry, which roughly says that moraic coda is a weaker licenser so that it requires more sonorous segments (Ito and Mester 1993, Prince and Smolensky 1993), dominates all other constraints. Second, PARSE and

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[4]Hayes (1986: 331) defines the Linking Constraint as follows:
Linking Constraint: Association lines in structural descriptions are interpreted as exhaustive.

[5]See Suh (to appear) for the detailed analysis of Persian Coda Weakening.

FILL family constraints, motivated from the faithfulness condition (Prince and Smolensky 1993) are ranked after *μw[-son]. Here, PARSE family constraints are interspersed between the FILL family constraints. Finally, *PLACE follows the above constraints. *PLACE is the reflection of coda underspecification, motivated from the inability of a coda to be its own sponsor (Heiberg in preparation, Steriade 1994). Figure (6) shows the ranking of the constraints in Persian.

(6) Ranking of the Constraints

*(w[-son]>>FILLseg>>PARSEseg>>PARSEfeat>>FILLfeat>>*PLACE

The following tableau will be useful in analyzing the candidates. Tableau (7) analyzes a non-geminate coda case.

(7)

<table>
<tr><td></td><td>/bo.ræv/
/\
Lab Cont</td><td>*μw
[-son]</td><td>FILL
seg</td><td>PARSE
seg</td><td>PARSE
feat</td><td>FILL
feat</td><td>*PLACE</td></tr>
<tr><td></td><td>a. bo.ræv
/\
Lab Cont</td><td>*!</td><td></td><td></td><td></td><td></td><td>*</td></tr>
<tr><td>☞</td><td>b. bo.row
/|\
Lab|Cont
<u>Son</u></td><td></td><td></td><td></td><td></td><td>*</td><td>*</td></tr>
<tr><td></td><td>c. bo.ræ.v_
/\
Lab Cont</td><td></td><td>*!</td><td></td><td></td><td></td><td></td></tr>
<tr><td></td><td>d. bo.ræ<v>
/\
Lab Cont</td><td></td><td></td><td>*!</td><td></td><td></td><td></td></tr>
</table>

Constraints are ordered left to right in order of priority. The pointing hand "☞" denotes the optimal output. "*" marks a violation of the constraint in that column, and "!" indicates a decisive violation. Unparsed elements are bracketed by "< >", and inserted elements are underlined "__". A dot "." indicates a syllable boundary.

Here, I assess only four of the infinite number of Gen for the expository purpose. If the above constraints are ranked so that *μw[-son] is more important than any other constraints, we get the desired result. (7a) is first eliminated because of the top-ranked *μw[-son] violation. (7c) and (7d) are also excluded by the violation of FILLseg and PARSEseg, respectively. Thus, (7b) is selected as the optimal output. Note here that Fill family constraints and PARSEseg constraint are violated on the surface to satisfy the higher ranked constraint *(w[-son].

Now, consider the geminate /vv/ case, which shows the geminate inalterability effect.

(8)

	/æv.væl[6]/ /\\ Lab Cont	*µw [-son]	FILL seg	PARSE seg	PARSE feat	FILL feat	*PLACE
☞	a. æv.væl /\\ Lab Cont						*
	b. ow. væl /| /\\ Lab|Lab Cont Son					**!	**
	c. ow.wæl /|\\ Lab| Cont Son					*!	*
	d. æ.v_. væl /| /| Lab|Lab| Cont Cont		*!			**	*
	e. æ<v>.væl /\\ Lab Cont			*!			*

In the above tableau (8), all the candidates satisfy *µw[-son] and PARSEfeat constraints. Especially, geminates /vv/ and /ww/ both meet *µw[-son] by the assumption of the geminate representation, since in the coda position they are not specified for the feature [sonorant]. However, (8b), (8c), and (8d) have all FILL family violation, in which [Son], not shown in the input ,appears on the output (8b & 8c), and an epenthetic vowel is added to avoid violating *µw[-son] constraint (8d). (8e) violates PARSEseg. Thus, (8a) is correctly selected as the optimal output among the candidates. This follows straightforwardly if we assume that the first half of the geminate (i.e. coda) is not specified at all for the features except for the ROOT node. In this way, geminate inalterability effects are accounted for without recourse to the doubly-linked structures of previous analyses.

3.2 Klingenheben's Law in Hausa

Let us consider another case where the constraint *µw[-son] plays an important role. The analysis of Hausa supports even more the analysis of the geminate inalterability effect shown in Persian. In this section, non-geminate coda weakening and the geminate coda inalterability effect in Hausa will be accounted for with the same constraint set and ranking as given in Persian.

A historical change known as Klingenheben's Law in Hausa which weakened (sonorized) coda obstruents (labials and velars –> /w/, alveolars –> /r/) became the synchronic condition that only sonorants appear in the coda position (Hayes 1986, Cho and Inkelas 1993). This rule failed to affect geminates; thus, obstruents can occur in the coda only when they are geminates.

[6]For the convenience I represent geminates using double consonants, but the exact representation of the geminates should be understood as shown in (2), in which the first half of the geminates is represented as nothing more than a bare root node.

(9) a.	/sabroo/	[sawroo]	`mosquito'
	/biyad/	[biyar]	`five'
b.	gulma		`mischief-making'
	abinci		`food'
c.	dabbaa		`animal'
	littaafi		`book'
	salla		`prayer'
	yamma		`afternoon'

As we can see in the examples (9a) and (9b), only sonorants appear in the coda position. However, obstruents appear in the coda so long as they are geminates as shown in the first two examples in (9c).

In the previous section, we observed Persian v--->w weakening in the coda position. In Hausa, the situation is rather complicated; Among stops, labials and velars are weakened to /w/ and alveolars to /r/. Thus, Persian shows weakening of a fricative to an approximant (/w/); Whereas Hausa shows weakening of stops to approximants (/w/ and /r/). When looked at from the viewpoint of Weakening or Lenition (Lass 1984), this is a natural movement since each step to the right increases the permeability of the vocal tract to airflow as shown in (10).

(10) Stop > Fricative > Approximant > Zero
(Lass 1984: 179)

In both Persian and Hausa, underlying a fricative and stops are realized as approximants, resulting in the coda sonorization effect. However, we need to make it clear that the exact phenomenon at issue is not sonorantization, but weakening; thus, nasal consonants are excluded from the possible candidates for the weakening process when evaluated, according to the weakening hierarchy (10). For that reason, we will not consider nasals as the possible candidates, hereafter.

The case of non-geminate coda (9a) is analyzed with tableau (11).

(11)

<table>
<tr><td></td><td>/sab. roo/
/| /|\
Lab| Cor |Cont
Son Son</td><td>*µw
[-son]</td><td>FILL
seg</td><td>PARSE
seg</td><td>PARSE
feat</td><td>FILL
feat</td><td>*PLACE</td></tr>
<tr><td></td><td>a. sab. roo
/| /|\
Lab| Cor|Cont
Son Son</td><td>*!</td><td></td><td></td><td></td><td></td><td>*</td></tr>
<tr><td>☞</td><td>b. saw. roo
/|| /|\
Lab ||Cor|Cont
Son| Son
<-Cont></td><td></td><td></td><td></td><td>*</td><td>*</td><td>*</td></tr>
<tr><td></td><td>c. sab.boo
/|
Lab| <Cor>
-Cont <Son>
<Cont></td><td></td><td></td><td></td><td>***!</td><td></td><td></td></tr>
<tr><td></td><td>d. sar. roo
/|\
Cor|Cont
<Lab> Son
<-Cont></td><td></td><td></td><td></td><td>**!</td><td></td><td></td></tr>
<tr><td></td><td>e. sa.b__.roo
/| /|\
Lab|Cor|Cont
-Cont Son</td><td></td><td>*!</td><td></td><td></td><td></td><td></td></tr>
<tr><td></td><td>f. sa<b>. roo
/| /|\
Lab|Cor|Cont
-Cont Son</td><td></td><td></td><td>*!</td><td></td><td></td><td></td></tr>
</table>

In the above figure, (11a), (11e), and (11f) are first eliminated by violating *µw[-son], FILLseg, and PARSEseg, respectively. Among (11b), (11c), and (11d) candidates, (11b) wins--even though it violates PARSEfeat, FILLfeat, and *PLACE, it is the only candidate to satisfy the three higher ranked constraints and have the least violation in PARSEfeat. The other competing candidates (11c) and (11d) are excluded since they have more severe violations in the PARSEfeat constraint.

Now, we turn to the geminate coda case, which shows the geminate inalterability effect.

(12)

<table>
<tr><th></th><th>/dab.baa/
/\
Lab [-Cont]</th><th>*μw
[-son]</th><th>FILL
seg</th><th>PARSE
seg</th><th>PARSE
feat</th><th>FILL
feat</th><th>*PLACE</th></tr>
<tr><td>☞</td><td>a. dab. baa
/\
Lab [-Cont]</td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td></td><td>b. daw. baa
/|| |\
Lab || Lab\
Son| [-Cont]
Cont</td><td></td><td></td><td></td><td></td><td>***!</td><td>*</td></tr>
<tr><td></td><td>c. daw. waa
/||
Lab ||
Son|
<-Cont></td><td></td><td></td><td></td><td>*!</td><td>*</td><td></td></tr>
<tr><td></td><td>d. da<b>.baa
/|
Lab|
[-Cont]</td><td></td><td></td><td>*!</td><td></td><td></td><td></td></tr>
</table>

In figure (12), candidates (12b), (12c), and (12d) are eliminated; (12d) violates PARSEseg. (12c) violates PARSEfeat and FILLfeat. (12b) violates FILLfeat. (12a) is chosen as the optimal output, showing again the geminate inalterability effect.

As we can see in the analyses of the Persian and Hausa data, geminates are not exceptional in any way under the current analysis which uses coda underspecification for the geminates and the constraint interaction model of Optimality Theory. In other words, geminates do not receive any special treatment since there is no concept of rule matching against the input structures having single or double association lines. In essence, we can freely operate on the geminate structures and the job of the constraints will block all but the optimal output.

4. Conclusion

Citing the coda weakening data from Persian and Hausa, I have provided strong empirical support for the hypothesis that the first half of the geminates is not linked but underspecified phonologically. I have also shown how the geminate inalterability effects are obtained through the constraints interaction model of Optimality Theory. This idea also will be extended to account for the behavior of geminates and other related phenomena.

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