Consonant weakening processes and Aperture Theory

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Consonant weakening processes may involve changes from phonetically long closure to short closure, from complete closure to some degree of approximation, and from approximation to deletion. The often gradient changes are hard to express in a feature geometric model because there is no unified set of features that accounts for them. I will propose a solution which employs aperture nodes. Short plosives involve a closure phase (represented by $A_0$ for zero aperture) and a release phase (represented here by $A_{rel}$). Long plosives have a long closure phase followed by a release phase and are represented by `$A_0 A_0 A_{rel}$' (of which the first aperture node is assigned to a coda position and the other two to an onset). Consonant weakening processes are analyzed as deletion of one aperture node, while consonant strengthening processes involve insertion of one aperture node.

Introduction

This paper discusses the problems that consonant weakening processes present for autosegmental analysis and offers a solution which employs aperture nodes rather than the stricture features [continuant] and/or [approximant]. Autosegmental phonology is premised on the notion that a segmental representation consists of tiers of features associated to one timing slot. A segment can be characterized by two values for a feature (see 1a) which yields a complex segment like an affricate, a pre- or postglottalized consonant, a pre- or postnasal, or a diphthong (e.g., Sagey 1986). Conversely, two adjacent segments can share one feature (see 1b), some features, or even the complete set of features.

\begin{center}
(1) \begin{tabular}{c}
\begin{tabular}{c}
 a \\
\hline
X
\end{tabular} \begin{tabular}{c}
/ \\
[-F] \[+F]
\end{tabular} \\
b \begin{tabular}{c}
X \\
/ \\
[-\alpha\ F]
\end{tabular}
\end{tabular}
\end{center}

It is striking that cross-linguistically, the feature [continuant] often displays the behaviour in (1a), but is never found in (1b). That is to say, affricates like $pf$ are common among languages, while we seldom find that the feature [+]continuant] spreads from a fricative to a following stop like in the hypothetical case $aspa \rightarrow asfa$, or deletes like in $efsa \rightarrow epsa$. Given the theory of autosegmental phonology in which spreading and delinking of features are the basic operations on segmental

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The present paper is a revision of parts of my 1995 dissertation. Sections of this paper were presented at the CLA-meeting, 28 May 1996. I thank Harry van der Hulst, René Kager, Carol Paradis, Glyne Piggott, Keren Rice, Mark Verhijde, and Wim Zonneveld for comments and discussions.
representations, the behaviour of [continuant] is unexpected. Furthermore, there is no explanation for the fact that complex segments like pre- and postnasals involve plosives (stops and affricates), rather than continuants (fricatives and approximants). In addition, consonant weakening processes may involve that phonetically long plosives are shortened in the same context in which short plosives are spirantized (Finnish), or that plosives are spirantized in the same environment in which fricatives are deleted (Irish), and these weakening processes are hard to express as a single autosegmental operation if we assume a feature [continuant].

Aperture Theory provides an explanation for these anomalies. The fact that [continuant] does not spread or delink and does not feature in the setup of (1b) suggests that it is not an autosegmental feature. To represent continuity in phonological representations, Steriade (1993a,b,1994) proposes to define the slots to which features attach in terms of degrees of oral aperture. This renders the use of a feature for continuity superfluous. Released stops and affricates are viewed as sequences of a closure followed by approximant or fricated release and have two Aperture nodes: one for the closure phase and one for the release phase. Fricatives and approximants have only one Aperture node for fricated or approximant release.

The explanation that Aperture Theory provides for the fact that complex segments are plosives is as follows. Aperture nodes are anchoring nodes for features. In the case of plosives, a feature may associate to either the Aperture node for closure or for release, or to both. In the case of continuants, one Aperture node is available as an anchor for features. This gives rise to a four-way distinction in the case of released plosives (see 2a), while continuants display a two-way contrast (see 2b,c). Steriade (1993a:73) illustrates this point for nasal, oral and partially nasal segments as follows, where $A_0$ stands for closure (aperture is zero), $A_{\max}$ for approximant release (maximal aperture) and $A_{\text{fric}}$ for fricated release (intermediate aperture generating turbulent airflow):

\[
\begin{align*}
(2) & \quad a & \text{nasal stop} & \quad \text{prenasal stop} & \quad \text{postnasal stop} & \quad \text{oral stop} \\
& & [\text{nasal}] & \quad [\text{nasal}] & \quad [\text{nasal}] & \\
& & \begin{array}{c}
\setminus \\
A_0 \quad A_{\max}
\end{array} & \begin{array}{c}
\setminus \\
A_0 \quad A_{\max}
\end{array} & \begin{array}{c}
\setminus \\
A_0 \quad A_{\max}
\end{array} & \begin{array}{c}
\setminus \\
A_0 \quad A_{\max}
\end{array}
\end{align*}
\]

\[
\begin{align*}
& \quad b & \text{nasal fricative} & \quad \text{oral fricative} \\
& & [\text{nasal}] & \quad [\text{nasal}] \\
& & \begin{array}{c}
\setminus \\
A_{\text{fric}}
\end{array} & \begin{array}{c}
\setminus \\
A_{\text{fric}}
\end{array}
\end{align*}
\]

\[
\begin{align*}
& \quad c & \text{nasal approximant} & \quad \text{oral approximant} \\
& & [\text{nasal}] & \quad [\text{nasal}] \\
& & \begin{array}{c}
\setminus \\
A_{\max}
\end{array} & \begin{array}{c}
\setminus \\
A_{\max}
\end{array}
\end{align*}
\]
In this paper I will consider the consequences of Aperture Theory for notoriously "hard to grasp" consonant weakening processes like Finnish Consonant Gradation, Modern Irish Initial Lenition, Modern Icelandic Spirantization, English t-weakening and Dutch d-weakening. It will be argued that they are best treated as deletion of an Aperture node, rather than deletion of a feature. I will also consider fortition processes and argue that these entail insertion of an Aperture node.

The organization of this paper is as follows. Section 1 considers consonant weakening processes which are induced by either the phonological environment, or by the morphological or syntactic environment. Linguists have referred to changes of this kind as "spectacular alternations" (Rotenberg 1978) or as "bizarre, irregular, and quirky phenomena" (Lieber 1987). In recent autosegmental literature, consonant weakening processes have been analyzed by phonological rules which change the value of stricture features, for example from underlying [+continuant] to [+continuant], and additional rules which ensure that an underlying [+continuant] specification results in deletion (or near deletion) of underlying features. Such rules are indeed "spectacular" and highly "irregular". In sections 2 to 5, it will be shown that consonant weakening processes in Finnish, Irish, Icelandic, English, and Dutch, respectively, are much less spectacular and only involve a deletion rule. Section 6 is devoted to the association of place features. Sections 7 to 7.2 consider Aperture nodes and laryngeal features and section 8 presents a summary.

1. Consonant Weakening

In different languages, we find that consonants are often transformed or "mutated" in a particular context. The mutations may involve changes from phonetically long closure to short closure (e.g., /t:/ --> [t]), form complete closure to approximation (e.g., /t/ --> [s]), and from approximation to deletion, and vice versa. This may be depicted as in (3):

(3) Changes in the manner of articulation:
Long Plosive <---> Short Plosive <---> Fricative/Approximant <---> Zero

Rightward changes are commonly referred to as "Weakening" or "Lenition", and changes in the reverse direction as "Strengthening" or "Fortition".

A well-known consonant weakening process conditioned by the morphological environment is Finnish Consonant Gradation. A word with a geminate stop in one morphological environment is realized with a short stop in another environment, while a word with a short stop alternates with an approximant under the same morphological conditions (examples from Skousen 1972, Vainikka 1988):
The environment in which we find that geminate stops are realized as single stops while single stops are realized as approximants is in the onset of a non-initial syllable which is closed during certain derivations. Skousen (1972:571) observes that the inessive suffix -ssää has changed to -sää in some dialects of Finnish, and even though it does not close the preceding syllable, it still induces Gradation. Conversely, some suffixes which close a preceding syllable do not change the form of the onset consonant in that syllable. An example is the masculine personal possessive suffix which closes a preceding syllable, but does not trigger gradation of the short stops t and k:

(6) a käite  p = [p]  'hand'
b käitesä  ph = [f]  'his hand'

(7) a puku  v = [w]  'clothes'
b pukunsa  fh = [f]  'his clothes'

The changes in manner of articulation depicted in (4b) and (5b) occur in exactly the same grammatical context and constitute one phonological process. In section 2, I will show how Aperture Theory enables us to express it as such.

Consonant weakening also occurs in Modern Irish. A word which is pronounced with an initial plosive in isolation is pronounced with an initial fricative when following the possessive pronoun mo 'my'. In the same environment, a word pronounced with the initial fricative ´f in isolation is realized without an initial consonant (examples from Ní Chiosáin 1991):

(8) a páipéar  p = [p]  'a paper'
b mo pháipéar  ph = [f]  'my paper'

(9) a fata  f = [f]  'a potato'
b mo fhata  fh = [f]  'my potato'

This phenomenon is known as Modern Irish Initial Lenition.

In Icelandic, we find that stops alternate with fricatives before t (examples from Thráinsson 1978):

(10) a gleypa  p = [pʰ]  'to swallow'
b gleypti  pt = [ft]  'swallowed'
c metta  t = [tʰ]  'to meet'
d metti  tt = [ft]  'met'
e vaka  k = [kʰ]  'to wake'
f vakti  kt = [xt]  'woke'
In most American dialects of English, $t$ is realized as a voiced alveolar tap [D] after a full vowel and before an unstressed vowel (examples from Kahn 1976), while in London English, intervocalic $t$ is pronounced as a glottal stop [ʔ]:

(11) a butter American English: $t t = [D]$, London English: $t t = [ʔ]$
b creative $t = [D]$
c obesity $t = [D]$

These forms of $t$-weakening, known as "flapping" and "glottaling", are not easily expressed in phonological rules which do not take Aperture nodes into account. A similar phenomenon is found in Dutch. In most dialects, $d$ is realized as an approximant after a vowel and before suffixal schwa:

(12) a goed en $d = [j]$ 'good ones' 
b gouden $d = [w]$ 'gold ones'

The next three sections will demonstrate that consonant weakening in Finnish, Irish, Icelandic, English, and Dutch, can be straightforwardly explained in the framework of Aperture Theory.

2. Finnish Consonant Gradation

In section 1, it is shown that a phonetically long stop in Finnish is shortened in the same context in which an underlying short stop is realized as an approximant. Vainikka (1988:2-3) proposes to capture this in a phonological rule which involves the following delinking and spreading operation. A [-sonorant,-continuant] specification of a syllable-initial stop is delinked from its C slot in a short syllable which is closed during certain derivations. Subsequently, the manner features of the preceding sonorant segment (i.e., [-continuant, +sonorant] in case of a nasal and [+continuant, +sonorant] in case of a vowel) spread to that slot. Her derivation for genitive tavan (from tapa + n) 'custom' (see 5) is given below:

(13) Manner Tier [+cont] [-cont]  
[+son] [-son]  
| \  |  |  |  
| \  |  #  
| \  |  |  |  
C  V  C  V + C 
(t a p a + n)  
Place Tier [+ant, -cor]  

Vainikka assumes that geminates have two slots on the CV-tier and share their features on other tiers. The first C slot of a geminate stop in Finnish is in coda position and the second in onset
position of the following syllable. The gradation rule that she proposes has the following effect on
geminates. The association line between the [-son,-cont] specification and the C slot in onset
position is crossed out, as for the short stop p in (13) above. Due to the intervening C slot in coda
position, however, the [+cont,+son] features of a preceding sonorant cannot spread in the case of a
geminate stop. To get the desired result, Vainikka has to make the ad hoc assumptions that a C slot
which is not associated to the Manner Tier, and which does not have independent place features,
deletes and that the remaining C slot resyllabifies as an onset. The derivation of lapun `paper' thus
proceeds as follows:

(14) Manner Tier

```
  [+cont] [-cont]  [+cont] [-cont]
  [+son] [-son]  [+son] [-son]
  | \  |  |  |  \
  | /  #  |  |  |
  | /  \  |  |  |
```

C V C C V + C  C V C V C
(1 a p $ p u + n) --->(1 a $ p u n)

Place Tier

```
  [+ant,-cor]  [+ant,-cor]
  |  |  |  |
```

Even though her account of Finnish Consonant Gradation is to a large extent a unified one in that
delinking of the features [continuant] and [sonorant] applies to both short stops and to geminates,
spreading only applies to short stops. I will now go on to show that it is possible to express
Consonant Gradation as one operation if we assume Aperture Theory.

I propose here that the consonant weakening processes discussed in section 1 involve
deletion of an Aperture node. For Finnish, Consonant Gradation involves deletion of an "A₀"
position at the left edge of the syllable which is closed during certain derivations. Consonant
Gradation thus entails that a short released stop is realized as an approximant, as is shown in (15):

(15)

```
  σ  σ
  / \  / \  /  / / \ \ /  \
  O N O N  O N O N Co
  t a [p] a + n  t a [w] a n ('custom')
```

Exactly the same process applies to geminates. With respect to geminates, consider that stops in
coda position are generally unreleased. In Steriade's framework, an unreleased stop is represented
as "A₀". The geminate consonant in (14) may thus be reanalyzed as a sequence of an unreleased
stop in coda position and a released stop in onset position, that is, as an "A₀ A₀ A_max" sequence:
The result of Gradation of phonetically long plosives is an Aperture node for closure followed by an Aperture node for release. These positions share all features and this sequence is thus interpreted as a short stop which is either ambisyllabic (as represented in 17), or forms an onset:

\[
\begin{array}{cccc}
\text{CON} & \text{O} & \text{N} & \text{CON} \\
\text{Ap} & \text{pp} & \text{u} \\
\text{Ap}_0 & \text{Ap}_0 & \text{Ap}_{\text{max}} \\
\text{ONCO} & \text{A}_{\text{max}} & \text{Ap} & \text{Ap}_0 & \text{N} & \text{CON}
\end{array}
\]

In summary, Finnish Consonant Gradation is accounted for as deletion of the initial Aperture node for closure:

\[
\begin{array}{cccc}
\text{CON} & \text{O} & \text{N} & \text{CON} \\
\text{Ap} & \text{pp} & \text{un} \\
\text{Ap}_0 & \text{Ap}_0 & \text{Ap}_{\text{max}} & \text{Ap} & \text{Ap}_0 & \text{N} & \text{CON}
\end{array}
\]

This analysis is supported by the fact that it also explains consonant weakening processes in other languages, e.g., morphologically induced Initial Lenition in Modern Irish.

3. Modern Irish Initial Lenition

Stops in Irish are realized as continuants under certain morphological and syntactic conditions, while continuants are deleted (or realized as a laryngeal sound). As an example of an autosegmental approach in which the feature [continuant] plays a predominant role, consider Ní Chiosáin's (1991) analysis of Modern Irish Initial Lenition.

Ní Chiosáin (1991) accounts for the changes in Irish consonants alluded to above by a "feature fill-in" rule. In her view, some obstruents are underlyingly unspecified for certain features which may be filled in by a phonological rule, or else by a redundancy rule. Stops, for instance, are assumed to be unspecified for the feature [continuant], the fricative /f/ is assumed to be specified as [+continuant], while /h/ is specified as [-son]:

\[
\begin{array}{cccc}
\text{a} & \text{/p,k,b,d,g/} & \text{b} & \text{/f/} \\
\text{[-son,+cons]} & \text{[-son,+cons]} & \text{[-son]}
\end{array}
\]
In environments where lenition does not apply a redundancy rule inserts the feature [-continuant] for stops and [+continuant] for /h/. In environments where lenition applies, for instance in (8b), the value [+continuant] is inserted by the Spirantization rule, i.e. the rule in (20) below:\(^2\)

\[(20)\]
\[
\begin{array}{c}
\text{Spirantization} \\
[ \text{Wd} \alpha ] \\
\rightarrow [+\text{continuant}] \\
\end{array}
\]

The sound /f/ undergoes the spirantization rule vacuously, because it is underlyingly specified as [+continuant], (see 19b). For this case, \(\text{Ní Chiosáin (1991:51)}\) proposes a default rule "Total Deletion", which only applies when the Spirantization rule applies vacuously. This seems theoretically "suspect".

The source of the problem concerning a phonological account of spirantization of stops and deletion of /f/ seems to be the assumed existence of the feature [continuant] in autosegmental phonology. Section 2 demonstrated that Aperture Theory is more useful to explain Finnish Consonant Gradation than an account based on the feature [continuant] and it will be argued next that the same is true for Modern Irish Initial Lenition.

Steriade (1993a,b) distinguishes between \(A_f\) and \(A_{max}\) for two reasons. First, \(A_f\) and \(A_{max}\) are used in segmental representations to distinguish between stops and affricates, and, second, they are used to distinguish fricatives and approximants. Some languages, however, do not have affricates and do not distinguish fricatives and approximants in underlying representations. In other words, these languages do not have a phonological distinction between \(A_f\) and \(A_{max}\) and I propose to indicate this by \(A_{rel}\) (for Aperture release). Modern Irish is such a language. Instead of \(\text{Ní Chiosáin's (1991)}\) representations of Irish obstruents in (19a-c), I propose (21), where C/L/D stands for either Coronal, Labial, or Dorsal:

\[(21)\]  
\[
\begin{array}{ccc}
\text{a} & /p,t,k,b,d,g/ & b & /f/ & c & /h/ \\
A_0 \ A_{rel} & A_{rel} & A_{rel} \\
\backslash / & \backslash / & \backslash / \\
\text{Place} & \text{Place} & \text{Place} \\
\backslash / & \backslash / & \backslash / \\
C/L/D & \text{Labial} & \\
\end{array}
\]

\(^2\) For the t–h and s–h alternations, \(\text{Ní Chiosáin proposes a different rule, which is not relevant to the discussion here.}\)
For Finnish, consonant weakening is straightforwardly explained as deletion of an initial Aperture node. The same operation accounts for Modern Irish Initial Lenition. In morphologically and syntactic conditioned environments, a word-initial Aperture node is deleted:  

(22) Modern Irish Initial Lenition as deletion of the initial Aperture node:

| initial stop | ---| fricative; | initial fricative | ---| \(\emptyset\) |
| # \(A_0\), \(A_{rel}\) | ---| \(A_{rel}\) | ---| \(A_{rel}\) |
| \(/\) | \(/\) | \(/\) | \(/\) |
| Place | Place | Place |
| \(C/L/D\) | \(L/D\) | Labial |

The Finnish and Irish examples discussed in sections 2 and 3 illustrate that phonological processes may involve the deletion of an Aperture node. The reverse process, that is the insertion of an Aperture node, is also attested.

In native American Southern Paiute (spoken in southwestern Utah and northwestern Arizona), short stops which, "by the process of derivation and composition, take up a medial position" (Sapir 1930:62) may be spirantized, nasalized, or lengthened following certain words. The lexical items sappi 'belly' and ava 'shade', for instance, cause spirantization, ago 'tongue' causes prenasalization, and a 'horn' causes gemination of the absolutive suffix -pi (data from Sapir 1931):  

(23) a b c d sappi + pi \(\rightarrow\) sappi\(\phi\) \(\rightarrow\) sappi\(\phi\) 'belly' (abs) 
    ava + pi \(\rightarrow\) avavi \(\rightarrow\) avavi 'shade' (abs) 
    ago + pi \(\rightarrow\) agompi \(\rightarrow\) agompi 'tongue' (abs) 
    a + pi \(\rightarrow\) api:Y \(\rightarrow\) api:Y 'horn' (abs) 

Spirantization in (23a-b) may be accounted for as deletion of A0, whereas gemination in (23d) involves insertion of A0. Prenasalization is accounted for as the association of a nasalizing feature to the initial aperture node of the suffix.

In West-African Fula, a continuant is sometimes realized as a stop. The stem baat 'needle', does not change its initial consonant in noun class 3, while weer 'host', for instance, appears with initial b in that class (Arnott 1970:98-101):

(24) a b c d baat + el \(\rightarrow\) baatel \(\rightarrow\) baatel 'needle' (diminutive sg.) 
    weer + el \(\rightarrow\) beerel \(\rightarrow\) beerel 'host' (diminutive sg.)

---

3 I account for the presence of the feature Coronal in the representation of the stops /t/ and /d/ and the absence of that feature in the representation of the corresponding fricatives in section 6 below.

4 Capitals are used to indicate voiceless vowels. The fact that underlying voiceless /p/ is not realized as [\(\phi\)] in example (23b) is due to the quality of the preceding vowel. In Southern Paiute, fricatives following voiced vowels are voiced.
Gemination of morpheme-initial short plosives in Southern Paiute and Fortition of stem-initial continuants in Fula are both accounted for as insertion of an initial Aperture node for closure:

(25) Southern Paiute Gemination as insertion of initial $A_0$:
short stop $\rightarrow$ long stop
$A_0 A_{\text{max}}$ $\rightarrow$ $A_0 A_0 A_{\text{max}}$

(26) Fula Fortition as insertion of initial $A_0$:
continuant $\rightarrow$ short stop
$A_{\text{max}}$ $\rightarrow$ $A_0 A_{\text{max}}$

For Fula, I propose that $A_0$ is inserted for word-initial continuants as well as stops in noun class 3.
In the case of stops, however, the inserted $A_0$ cannot be syllabified and is consequently not realized.

Mutations affecting the manner of articulation in Finnish, Irish, Southern Paiute, and Fula may seem "spectacular" and "bizarre" at first sight, but, in fact, all that is involved at the level of phonology is the deletion (or, conversely, the insertion) of one Aperture node. We will now provide more independent evidence for the deletion of Aperture nodes.

4. Icelandic Spirantization

In Icelandic, two adjacent identical aspirated stops are realized as $h +$ stop (data are taken from Thráinsson 1978):

(27) a kappi $\rightarrow$ pp=[$hp$] 'hero'
b hattur $\rightarrow$ tt=[$ht$] 'hat'
c pakka $\rightarrow$ kk=[$hk$] 'thank'

Two heterogenic aspirated stops are realized as fricative + stop (i.e. aspirated stops spirantize before other aspirated stops):

(28) a hlaupe (stem: hlau) $\rightarrow$ to jump' $\rightarrow$ hlauptu $\rightarrow$ pt=[ft] 'jump !'
b sitja (stem: sit) $\rightarrow$ to sit' $\rightarrow$ situ $\rightarrow$ tt=[ht] 'sit!' c leika (stem: leik) $\rightarrow$ to play' $\rightarrow$ leiknu $\rightarrow$ kt=[xt] 'play!'

Preaspiration and Spirantization occur when two stops are adjacent. The effect is that the first stop loses its Aperture node for closure, as is illustrated for (28a) below:
The first stop also loses its place feature if it is identical to the place feature of the following stop (presumably due to an OCP constraint on adjacent place features). This can be illustrated for (27a) as follows:

(30) The first stop also loses its place feature if it is identical to the place feature of the following stop (presumably due to an OCP constraint on adjacent place features). This can be illustrated for (27a) as follows:

To summarize, (31) schematically represents the loss of an Aperture node in a sequence of two stops in Icelandic:

(31) Modern Icelandic Spirantization and Preaspiration as deletion of \( A_0 \)

\[ \text{stop} \rightarrow \text{fricative} \]

\[ A_0 A_{rel} \rightarrow A_{rel} A_0 A_{rel} \]

5. English t-weakening, and Dutch d-weakening

In most English dialects of North America, Australia, Ireland and parts of England, the coronal sounds \( t \) and \( d \) are weakened and realized as an alveolar flap before an unstressed vowel (see 32a-c):

(32) a pretty pre[D]y
b creative crea[D]ive
c odor o[D]or

This, too, can be explained as deletion of an Aperture node. A stop in intervocalic position is weakened and loses one Aperture node. What remains in North American, Australian, and Irish dialects of English is the Aperture node for closure with coronal place of articulation and some voicing (probably due to surrounding sonorant segments), which characterizes the flap. What remains in the glottalizing dialect is the Aperture node for release. There is no closure in the oral cavity (and, hence, no place of articulation) and no voicing. This is interpreted as a glottal stop.
Observe that consonant weakening in these dialects only applies to alveolar stops and not to labial or velar stops. We will not be concerned in too much detail with the reasons for the special status of coronal sounds in languages (see, e.g., Paradis & Prunet 1991). What is relevant to the present discussion is that deletion of an Aperture node also takes place in English. I assume that the Coronal place feature is not specified in underlying representations in English, whereas the Labial and Dorsal place features are. A closure in the vocal tract (A0) implies a place of articulation, but absence of closure (AreI) does not call for a specification of place of articulation. For this reason, the default place of articulation, i.e. Coronal, is added in the case of oral closure (33a), but not in the case of release (33b). A provisional characterization of Flapping and Glottaling is as follows:

(33) a. Flapping as deletion of A_max :
   \[ V A_0 A_{max} V \rightarrow V A_0 V \]
   \[ \text{Place} \]
   \[ \text{Coronal} \]

b. Glottaling as deletion of A0 and [constricted glottis] enhancement:
   \[ V A_0 A_{max} V \rightarrow V A_{max} V \]
   \[ \text{[constr gl]} \]

Speakers of Dutch may optionally replace the coronal voiced stop \( d \) with an approximant after full vowels and before suffixal schwa (Zonneveld 1978). I analyze this process as one in which the coronal voiced stop loses its closure phase:

(34) Dutch \( d \)-Weakening as deletion of A0:
   \[ SV \rightarrow SV \]
   \[ V A_0 A_{rel} + \varepsilon \rightarrow V A_{rel} \varepsilon \]
   \[ \text{Coronal} \]

After most tense vowels and diphthongs, \( d \) in Dutch is realized as the palatal approximant \( j \), but after the diphthong /au/ the labial-velar approximant \( w \) appears:

(35) a. \( \text{raden} \rightarrow \text{ra[j]en} \) 'to guess'
b. \( \text{rode} \rightarrow \text{ro[j]e} \) 'red' (attributive)
c. \( \text{goede} \rightarrow \text{goe[j]e} \) 'good'
d. \( \text{gouden} \rightarrow \text{gou[w]e} \) 'golden'

Between two adjacent vowels in Dutch words, an approximant is usually inserted. For this reason, it may be suggested that Dutch \( d \)-weakening is a process of \( d \)-deletion and subsequent glide-
insertion. Observe, however, that in the cases of glide-insertion between two vowels, the first vowel determines whether the hiatus consonant is the palatal or labial-velar approximant and there is no hiatus consonant between a and another vowel:

b intrusive [w] boa [bo:wa] egoisme [e:go:wisma]  
c no intrusive approximant naief [na:iʃ] chaos [xaːʃs]

D-weakening in (35a) is different from the case presented in (36c) in that d seems to leave a "trace" in the form of an approximant which, judging from the absence of a hiatus consonant in (36c), is not attributable to the rule of glide-insertion between two vowels. I propose here that this "trace" is the Aperture node for release (see 34). Due to a constraint on two adjacent glides, this position merges with the preceding diphthong in, e.g., (35d):

(37) /X a w d + ə/ [X a w ə]  
C V G C  
\ / \  
A_vow A_max A_0 A_max --> A_vow A_max A_max --> A_vow A_max  
Dor Cor Dor Cor Dor

So far, we have seen that in certain morphologically determined environments stops in Finnish may lose one Aperture node for closure and word-initial segments in Irish may lose one Aperture node for either closure or release. Furthermore, in phonologically determined environments stops in Icelandic may lose one Aperture node for closure and intervocalic stops in English may lose one Aperture node for either closure or release (depending on the dialect). In Dutch the Aperture node for closure is deleted after a full vowel and before suffixal schwa.

6. Aperture nodes and Place features

The location of the closure or partial obstruction in the vocal tract is represented by place features which are related to Aperture nodes. If we are right in assuming that consonant weakening entails the deletion of an Aperture node, we are faced with the following issues concerning the representation of place. In Finnish, the labial and coronal short stops are realized as labial and
coronal approximants, respectively, in gradation environments. According to Vainikka (1988:10), the velar stop displays the following alternations. The gradated \( k \) is realized as the palatovelar glide [\( \dddot{y} \)] if followed by [e] (see a), as the labial glide [w] if surrounded by the stressed high rounded vowels [u] or [ü] (see b), and not realized otherwise:

\[
\begin{array}{llll}
(38) & a & \text{kurki} & \rightarrow & \text{kurjen} & j =[\dddot{y}] & \text{`stork'} \\
& b & \text{luku} & \rightarrow & \text{luvun} & v = [w] & \text{`chapter'} \\
& c & \text{suka} & \rightarrow & \text{suan} & & \text{`brush'}
\end{array}
\]

In Irish, lenited labial and velar stops retain their place of articulation. The coronal voiceless stop, however, is realized as a laryngeal fricative and the voiced stop as a velar fricative (data from Kelly 1989:6):

\[
\begin{array}{llll}
(39) & a & \text{teach} & t = [\dddot{t}] & \text{`a house'} \\
& b & \text{mo theach} & th = [\dddot{h}] & \text{`my house'} \\
& a & \text{dúnaimid} & d = [d] & \text{`we close'} \\
& b & \text{dhúnamar} & dh = [\dddot{y}] & \text{`we closed'}
\end{array}
\]

Finnish, Irish, some dialects of English, and Dutch have in common that weakening of a short plosive results in an Aperture node for release. The differences are that (i) weakening may apply to all short stops in Finnish and Irish, but only to coronal stops in English and to \( d \) in Dutch, and (ii) the consonants that seem to lose their place features in the respective weakening process are the velar stop \( k \) in Finnish, the coronal stops \( t \) and \( d \) in Irish, and the coronal stop \( t \) in dialects of British English.

With respect to place features, Rice (1993) proposes the following. In representations where a C-Place node does not have a dependent, either the universally unmarked feature can be filled in (i.e. Coronal), or the unmarked feature fails to be filled in and the segment is realized through interpretation of the inherent content of the Place node itself. When the Coronal feature is not filled in by default, the Place node remains bare and is interpreted as `velar'. The difference between coronals and velars is a consequence of whether the Coronal default value applies or not:

\[
\begin{array}{llll}
(40) & a & \text{underlying} & \text{default} & \text{surface coronal} \\
& \text{Root} & \rightarrow & \text{Root} \\
& | & \rightarrow & | \\
& \text{Place} & \rightarrow & \text{Place} \\
& | & \rightarrow & | \\
& \text{Coronal}
\end{array}
\]

\[
\begin{array}{llll}
& b & \text{underlying} & \text{surface velar} \\
& \text{Root} & \rightarrow & \text{Root} \\
& | & \rightarrow & | \\
& \text{Place} & \rightarrow & \text{Place}
\end{array}
\]
An Aperture node for closure entails that there is complete obstruction of the airflow in the mouth. In other words, where there is A0 there should be a place of articulation. I here propose that the difference between consonant weakening of \(/k/\) in Finnish and of \(/l/\) in Irish is as follows. In both languages we are dealing with segments which are underlyingly unspecified for a place feature. In Finnish stops, C-place is phonetically interpreted as velar while in Irish stops Coronal is added by default:

\[
\begin{align*}
\text{(41) a} & \quad \text{Finnish:} & A0 & \text{Amax} & \text{interpreted as velar stop} \\
& & \backslash & / & \text{Place} \\
\text{b} & \quad \text{Irish:} & A0 & \text{Amax} & \text{default:} & A0 & \text{Amax} \\
& & \backslash & / & \text{Place} & \backslash & / \\
& & & & \text{Place} \\
& & & & \text{Coronal}
\end{align*}
\]

When the Aperture node for closure is deleted in Finnish, place features for A_{rel} are supplied by surrounding vowels. The vowel \(a\), however, does not supply place features. An Aperture node for release without place features is not interpretable in Finnish and for this reason weakening of \(k\) results in deletion in (38c). When the Aperture node for closure is deleted in a morphological environment in Irish, the Coronal default rule fails to apply. An Aperture node for voiceless release is interpreted as laryngeal \(h\) in Irish and an Aperture node for voiced release is interpreted as a velar fricative.

\[
\begin{align*}
\text{(42) Finnish} & \quad A0 & \text{Amax} \longrightarrow & \text{Amax} & \text{(place features supplied by neighbouring vowels)} \\
& & \backslash & / & \text{Place} \\
\text{Irish} & \quad A0 & \text{Amax} \longrightarrow & \text{Amax} & \text{(interpreted as a laryngeal fricative when voiceless)} \\
& & \backslash & / & \text{Place} \\
& & & & \text{Place} \\
& & & & \text{(interpreted as a velar fricative when voiced)}
\end{align*}
\]

7. Aperture nodes and Laryngeal Features

All consonant weakening processes manifest themselves as a decrease of consonantal stricture. The theory developed on independent grounds in Steriade (1993a,b) seems particularly suited to capture this fact, i.e. a decrease of stricture is analyzed as the loss of an Aperture node (sometimes accompanied by the loss of place features). An increase of stricture is analyzed as insertion of an Aperture node. Steriade (1994) suggests one other option, viz. the merger of two Aperture nodes.
For instance, aspiration on word-initial consonants in Huautla Mazateco, an Otomanguean language of Oaxaca, Mexico, is the result of the merger of an Aperture node with aspiration and an Aperture node of the initial consonant in question. We will illustrate this in section 7.1 and discuss the consequences for Modern Welsh Initial Lenition in 7.2.

7.1 Aperture nodes and Onsets with Aspiration in Mazateco

Steriade (1994:219) presents the following consonant inventory:

<table>
<thead>
<tr>
<th></th>
<th>labial</th>
<th>alveolar</th>
<th>strident</th>
<th>postalveolar</th>
<th>retroflex</th>
<th>velar</th>
<th>laryngeal</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>b</td>
<td>t</td>
<td>ts</td>
<td>f</td>
<td>tʃ</td>
<td>k</td>
<td>?</td>
</tr>
<tr>
<td></td>
<td>s</td>
<td>j</td>
<td>sʃ</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>m</td>
<td>n</td>
<td>l</td>
<td>nʃ</td>
<td>y</td>
<td>h</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

In Mazateco, we find a complex pattern of onset consonants including pre- and postglottalized plosives, pre- and postaspirated plosives, prenasalized plosives and prenasalized aspirated plosives. In the present section, we concentrate on aspiration.

The laryngeal segments /h/ and /ʔ/ may appear on their own in Mazateco. Steriade (1994) analyzes /h/ as an $A_{\text{max}}$ position with the feature [spread] for aspiration and [ʔ] as an $A_{\text{max}}$ position with the feature [constricted]:

(44) a /h/ $A_{\text{max}}$ b /ʔ/ $A_{\text{max}}$

\[[\text{spread}] \quad \text{[constricted]}\]

In Mazateco, plain consonants are available landing sites for the features of aspiration and glottalization. The restriction seems to be that the one feature excludes the other. Onset consonants may be preaspirated or postaspirated and preglottalized or postglottalized, but not, e.g., preaspirated-postglottalized. In the course of this section, it will become clear that this follows from the fact that aspirated and glottalized onset consonants are monosegmental and only one laryngeal feature is allowed per segment.

In onset position, plosives may be preaspirated, while nasals are partly devoiced:

(45) a hti

\[ht = [\text{h}t] \quad \text{'fish'}\]

b htse

\[hts = [\text{h}t\text{s}] \quad \text{'a sore'}\]

c hno

\[hn = [\text{n}] \quad \text{'corn'}\]
To explain the distribution of preaspirated consonants in onset position, Steriaede (1994:233-234) suggests a merger of Aperture nodes in the formation of onsets. Onsets with preaspiration are generated by the following merger process whose output is a monosegmental sequence of Aperture nodes. This is compatible with the fact that aspiration is phonetically realized as simultaneous with at least the first half of the stop closure:

(46) a  Merger deriving hC onsets:  
\[
\begin{array}{c}
A_{\text{max}} \\
A_0 \rightarrow \\
A_0 \ A_{\text{max}}
\end{array}
\]

b  Merger deriving hN onsets:  
\[
\begin{array}{c}
A_{\text{max}} \\
A_0 \rightarrow \\
A_0 \ A_{\text{max}}
\end{array}
\]

In Icelandic, /h/ may appear in coda position and a plosive in onset position of the next syllable. In other positions, e.g. word-initially, /h/ is realized as aspiration on plosives and as devoicing on sonorants:

(47)  
a.  hljo’s  \[hljo’s\]  ‘light’  
b.  hnifur  \[hnifur\]  ‘knife’

This seems to suggest that the merger (46) of Aperture nodes in onsets also applies in Icelandic. Furthermore, this analysis finds independent support from Welsh, as will be shown next.

7.2 Aperture nodes and Onsets with Aspiration in Welsh

According to Ball & Jones (1984), the voicing contrast on Welsh plosives is phonetically realized as the presence or absence of aspiration. Grijzenhout (1995:164) gives the following inventory for Welsh consonants:

(48) Modern Welsh consonants

<table>
<thead>
<tr>
<th>labial</th>
<th>alveolar</th>
<th>strident</th>
<th>velar</th>
</tr>
</thead>
<tbody>
<tr>
<td>stops</td>
<td>p, ph, h, t</td>
<td>k, kʰ, k</td>
<td></td>
</tr>
<tr>
<td>fricatives</td>
<td>f, s, x</td>
<td></td>
<td></td>
</tr>
<tr>
<td>nasals</td>
<td>m, n, ñ, ɲ</td>
<td>ñ, ɲ</td>
<td></td>
</tr>
<tr>
<td>liquids</td>
<td>l, l, r, ř, ɾ</td>
<td>o</td>
<td></td>
</tr>
</tbody>
</table>

As in Irish (see section 3), word-initial consonants may be mutated in certain morphological or syntactic environments. Even though the attested consonant alternations are different from Modern
Irish, we will maintain that the phonological process is the same, viz. the deletion of the word-initial Aperture node.

In Welsh Lenition environments, aspirated plosives are realized as unaspirated plosives, unaspirated plosives as fricatives, fricatives are not affected, and devoiced sonorants are fully voiced. The following examples are from Willis (1986:10):

(49)  
   a  pen  p = [pʰ]  'head'  
   b  ei ben  b = [p]  'his head'  

(50)  
   a  brawd  b = [p]  'brother'  
   b  ei frawd  'his brother'  

(51)  
   a  llong  l = [ɬ]  'ship'  
   b  ei long  l = [l]  'his ship'  

In accordance with the analysis of consonant weakening processes in Finnish and Irish proposed above, I will analyze Welsh Initial Lenition as deletion of the first Aperture node. Contrary to Irish, fricatives are not affected in Welsh due to the fact that an Aperture node must remain to fill the onset (see 52c). With Steriade (1994), I assume that aspiration is carried by a separate Aperture node for laryngeal release. The analysis I propose for the data in (49-51) runs as follows:

(52)  
   a  aspirated plosive  --->  unaspirated plosive  
   [spread]  
   |  A_rel  A_0  A_rel  --->  A_0  A_rel  
   b  unaspirated plosive  --->  fricative  
   |  A_0  A_rel  --->  A_rel  
   c  fricative unaffected (due an obligatory onset consonant)  
   |  A_rel  
   d  devoiced sonorant  --->  fully voiced sonorant  
   [spread]  
   |  A_rel  A_rel  --->  A_rel  
   |  lateral  lateral

In environments where lenition does not take place, /l/ merges with the following onset consonant as in (46) for Mazateco.
8. Conclusion

Consonant mutations may involve (often gradient) changes from phonetically long closure to short closure (e.g., p: ---p), from complete closure to some degree of release (e.g., p: --> f, or, p: --> w), and from some degree of release to total deletion (e.g. f: --> 0), and vice versa. These changes are hard to grasp in a feature geometric model because there is no unified set of features that accounts for them. On the basis of data from the languages such as Finnish, Irish, and others which exhibit consonant weakening processes and languages such as Southern Paiute and Fula which exhibit consonant strengthening processes, I propose a solution which employs aperture nodes rather than the stricture features [continuant] and [approximant]. Short plosives involve a closure phase (represented by A0 for zero aperture) and a release phase (represented here by AreI). Long plosives have a long closure phase followed by a release phase and are represented by `A0 A0 AreI' (of which the first aperture node is assigned to a coda position and the other two to a following onset). Consonant weakening processes are analyzed as deletion of one aperture node, while consonant strengthening processes involve insertion of one aperture node:

(53) long plosive  <---> short plosive  <---> continuant  <---> deletion
A0 A0 AreI     A0 AreI      AreI      0

I argue that the scale in (53) represents an encoding of sonority, which allows a change to a sound that is one degree more or less sonorant than the underlying sound. We never find changes from, for example, long plosives to continuants due to the fact that such a process would involve two sonority dimensions (phonetic length as well as degree of aperture in the vocal tract).

To conclude, this paper shows that consonant mutations are difficult to account for by traditional manner features, whereas Aperture Theory offers a unified account of these processes.

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