Contrast Maximization and Sonority: A Functional Approach*

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This paper explores the functional goal governing the pattern of permissible codas in many languages. I argue that the choice of more sonorous consonants in syllable codas, but not in onsets, can be accounted for by a phonological strategy to maximize contrast. Based on the proposal that syllable codas are less prominent linguistic positions (Beckman 1997), certain types of segments are argued to be less salient than any other segment types, thus frequently deleted or neutralized in syllable codas. I argue that to prohibit deletion or neutralization of less salient segments and preserve their contrast in syllable codas, more salient segments, namely, more sonorous segments are chosen. In terms of saliency ranking, stops are argued to be the least salient segments, and thus not likely to be chosen as syllable codas. The weak saliency of stops as compared to other types of segments is shown to be acoustically supported.

1. Introduction

An observation of the preferable coda patterns of syllables in many languages is that more sonorous segments are preferred in syllable codas, but not in syllable onsets. Thus stops, the least sonorous segments, are less frequently syllabified as codas. The preferred order or type of segments within a syllable has been explained, traditionally resorting to the notion of "sonority" or "consonant strength". Taking up the notion of "sonority", for example, these approaches propose either independent principles requiring codas to be of high sonority (Clements 1990), or the constraints on syllable

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contact that a sequence of rising sonority is prohibited over a syllable boundary (Vennemann 1988; Bat-El 1996). Both approaches can provide insightful observation that only codas, not onsets, prefer more sonorous segments. However, neither approach provides an independent explanation for 1) why more sonorous segments are preferred or allowed in this prosodic position; and 2) why only codas, but not onsets, prefer sonorous segments.

This paper attempts to answer these two questions in the framework of functional phonology (Boersma 1999; Flemming 1995), primarily based upon the acoustic evidence. More specifically, I provide an account for the pattern that among various kinds of consonants, stops are least likely to be chosen as syllable codas. In section 2, I review previous literature on sonority principles of the preference for more sonorous codas as well as general preferred syllable types. Among various versions of sonority principles, the most recent proposal by Bat-El (1996) is examined. Section 3 is my proposal. I show that the preference of more sonorous segments in syllable codas can be explained as a phonological strategy to preserve the contrast of coda segments, since syllable codas are less prominent linguistic positions, and thus segments in syllable codas are frequently deleted or neutralized. In this sense, stops, the least sonorous segments, are shown to be prohibited as syllable codas. In section 4, I provide acoustical evidence for the proposal that least sonorous segments such as stops are not acoustically salient, while other types of more sonorous segments like fricatives, nasals, or liquids are relatively salient for syllable codas. Section 5 concludes this paper.

2. Sonority Principles

Sonority is a well-known motivation for the preference of certain types of syllable structures and syllable contacts. Even though there has been little agreement among phoneticians and phonologists on the question of what "sonority" is, sonority-related principles have brought light to a number of generalizations as to marked or unmarked syllable types. In particular, several versions of sonority sequencing principles have been proposed to account for the preferred order of segments within the syllable (Greenberg 1978, Sievers 1881, Jespersen 1904, Selkirk 1982). According to these principles, segments are ranked along a sonority scale and segments ranking higher in sonority stand closer to the center of the syllable. For example,

the sonority scale proposed by Bat-El (1996) is given in (1).

(1) sonority scale:

vowels > glides > liquids > nasals > fricatives > stops
5 4 3 2 1 0

(Bat-El 1996 : 303)

The sonority sequencing principle based on the sonority scale is given in (2).

(2) Sonority Sequencing Principle:
Between any member of a syllable and the syllable peak, only sounds of higher sonority rank are permitted.

(Clements 1990 : 285)

Under this principle, /tra/, for example, is permitted in English, while /rta/ is excluded, since the sonority scale of "stops" is lower than that of "liquids" in /rta/.

The principle in (2) predicts that the order of segments in syllable codas tends to resemble the "mirror image" of the order of onset segments as far as their sonority profile is concerned. However, when languages allow both sonorants and obstruents in syllable codas, the set of obstruents which can occur there is frequently smaller than the set of permissible sonorants. To account for this, several proposals have been given: the "Dispersion Principle" by Clements (1990); "Syllable Contact" principles by Vennemann (1988) and Bat-El (1996). Among these, Bat-El (1996) proposes the following constraints within the Optimality theory (Prince and Smolensky 1993 and subsequent studies) as given in (3).

(3) Syllable Contact Family:
a. Syllable Contact (σ Cont): "The onset of a syllable must be less sonorous than the last segment in the immediately preceding syllable"
b. Syllable Contact Slope (σ ContSlope): "The greater the slope in sonority (between the onset and the last preceding segment in the immediately preceding syllable) the better"

(Bat-El 1996 : 304-305)

The constraint *Syllable Contact Slope* (σ ContSlope) refers to the general

sonority sequencing principle as in (2), based on the different degrees of sonority distance. On the other hand, the constraint *Syllable Contact* (σ Cont) accounts for the observation that in many languages, more sonorous segments are preferred for syllable codas, since this constraint requires the onsets to be less sonorous than the preceding codas. Thus these two constraints are universally ranked as in (4).

(4) σ Cont >> σ ContSlope

Bat-El's constraints in (3) are based on Hebrew blending processes. For example, when the two words of /kibuc/ 'collective settlement' and /moʃav/ 'cooperative settlement' are blended, the possible output is [moʃ.buc], not [kib.ʃav], because the form of [kib.ʃav] violates the constraint *σ Cont*. The segment [b], the coda of the preceding syllable is less sonorous than the onset of the following syllable, [ʃ].

A serious problem can be raised with these sonority relevant principles. In either *σ Cont* or "Dispersion Principle" by Clements (1990), the permissible coda patterns may be observed, but not explained. These principles can characterize the permissible coda patterns accurately and straightforwardly, and thus can predict which segments are preferred and which segments are less preferred or prohibited in syllable codas. However, they cannot offer independent explanation why such segments are preferred or less preferred in codas. In other words, it cannot be explained in these approaches why more sonorous segments are preferred in syllable codas and why stops, the least sonorous segments, are not likely to be chosen as syllable codas. Also it remains ambiguous why only codas show such restrictive selection of segments in syllabification while onsets tolerate segments with the lowest ranking of sonority. To resolve these issues, a better motivated explanation for the constraint *σ Cont* or the "Dispersion Principle" is called for.

3. Proposal

I propose a functional account to provide a motivated solution for the onset/coda asymmetry in the syllabification pattern that only codas prefer more sonorous segments, which is represented as the constraint *σ Cont* (Bat-El 1996) or the "Dispersion Principle" (Clements 1990). My argument is based on the so-called "positional faithfulness" constraints by Beckman (1997). Beckman identifies privileged and non-privileged positions on the

basis of psycholinguistic or perceptual prominence, and argues that marked segments or features are confined to privileged positions. Those are, for example, initial syllables, stressed syllables, syllable onsets, or root syllables. Since phonological contrasts are preferentially maintained in these positions, a family of constraints which regulate input-output correspondence in only these privileged positions generally dominate other constraints.

Among many privileged positions discussed above, it can be maintained that syllable onsets, but not codas are associated with a wide range of features or segments. Since segments in the syllable onsets can be more easily produced and/or perceived, syllable onsets can convey features for even phonetically marked or perceptually difficult contrasts. In optimality theoretic grammar, this can be formally explained by high-ranking faithfulness constraints for syllable onsets (See Beckman 1997 for a detailed analysis). As compared to the privileged status of syllable onsets, syllable codas are relatively less prominent linguistic positions, psycholinguistically or phonetically. Thus features or segments in syllable codas are harder to identify or distinguish than those in syllable onsets. This leads to the fact that segments or features in syllable codas are frequently deleted, neutralized or changed to other segments through assimilation. A wide range of such phonological processes in syllable codas are attested, some of which are examined later in this section.

As proposed by Silverman (1998), if a certain contrast is not phonological and/or do not provide sufficient energies to preserve that contrast, it can be easily obliterated through phonological processes such as deletion or neutralization.[1] However, if a certain contrast is phonological and with enough energies available, as in the case of English syllabification, it is likely to be maintained. There could be various ways to preserve such phonological contrast. One of them is to strengthen the weak segments in syllable codas to be more salient, thus resisting deletion or neutralization. My primary hypothesis is that these phonological strategies can be extended to the syllable structure constraints. When syllabified for codas, only segments equipped with sufficient amount of saliency are permissible. Since only salient segments are stable in syllable codas, less salient segments such as stops and fricatives are not or are less preferred.

This account intuitively captures the relevant contrast of consonants in

[1] German final devoicing or manner neutralization in Korean are such examples. See Steriade (1996) for more detailed analysis.

the syllabification of codas. Based on these accounts, the sonority of segments can be reinterpreted in terms of linguistic saliency of segments. The ranking of consonants which can be syllabified as codas is as follows.[2]

(5) stops < fricatives < nasals, liquids, glides

The ranking in (5) looks similar to that as sonority, and actually in many languages, the output of the ranking of either saliency or sonority is without any difference. But the sonority and saliency proposed here are distinguished in two respects. First, the saliency of segments is phonetically grounded: the ranking is determined by whether each segment can provide sufficient acoustic information, which is discussed in detail in the following section. However, the phonetic correlate of sonority is still controversial: any single physical definition of sonority has not been found up to now. Rather this notion is argued to be associated with speech perception, not production. Second, as the saliency of segments is based on acoustics, its ranking in (5) is language-universal. This can be compared to the language-particular scale of sonority. At least in the present explanation of the syllabification of codas, however, these two notions can be interchangeable, and thus I use both terms in this paper.

Following the ranking of segments in terms of saliency, stops are less permitted than any other types of consonants such as fricatives, nasals, liquids and glides; fricatives are less permitted than other sonorant consonants such as nasals, liquids and glides.[3] Thus we can predict that stops and fricatives are less frequently syllabified as syllable codas, and if such consonants are posited as syllable codas, they are frequently changed to more sonorous, i.e. more salient, segments through phonological processes. English coda patterns prohibiting stops are now accounted for in a natural way, without resorting to the stipulative "Dispersion Principle" (Clements 1990).[4] Stops are not salient in linguistically less prominent positions,

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[2] The ranking of sonorants (nasals, liquids, glides) in terms of saliency in (5) is not discussed in the present paper.

[3] As pointed out by an anonymous reviewer, to strengthen my argument, the ranking of saliency as proposed in this paper needs to be supported by cross-linguistic evidence that languages with stops as syllable codas are less frequently found than languages with fricatives and nasals, for example, languages with fricatives as syllable codas are less frequently shown than those with only sonorants and so on. I leave this for further research.

leading to the frequent application of deletion of stops in syllable codas. To prohibit the deletion of segments and preserve the contrast, more salient - sonorous - segments should be posited in syllable codas.

In the following, I examine various phonological processes to show contrastive behaviour of stops (and fricatives) as discussed in the literature following the phonological approach. First, in various deletion patterns, stops contrast with fricatives and nasals in syllable codas: stops are more subject to deletion. Catalan (Côté 1997), for example, is one such example.

(6) Catalan (Mascaró 1983, 1989, Wheeler 1986, 1987)

a.	/-rs/	/curs/	→	[kurs] *[kur]	'course'
	/-rn/	/karn/	→	[karn] *[kar]	'meat'
	/-ls/	/pols/	→	[pols] *[pol]	'dust'
	/-ns/	/fons/	→	[fons] *[fon]	'bottom'
b.	/-rt/	/fort/	→	[for]	'strong'
	/-lt/	/alt/	→	[al]	'tall'
	/-nt/	/punt/	→	[pun]	'point'
	/-st/	/bast/	→	[bas]	'vulgar'

(Côté 1997)

Fricatives or nasals always stay as in (6a), while stops are deleted in syllable codas as in (6b).

Another example involves g/ç alternation in German as in (7), where the velar stop /g/ in final position undergoes /g/-spirantization, producing the palatal fricative, [ç].

(7) Modern standard German

köni[ç]	'king'	köni[g]e	'kings'
weni[ç]	'few'	weni[g]er	'fewer'

(Hahn 1998 : 5)

On the other hand, when the velar stop is syllabified as an onset of the

[4] Note that stops are not argued to be completely banned in English codas. Rather it is argued that other phonation types are preferable in this prosodic position. Exceptional examples permitting stops in syllable codas are, for example, as follows: *chapter, capsule, abdomen, pretzel, factor, pixel, rapt, lapse, ritz, fact, tax* in English. Other languages such as Classical Greek, Latin or Balti also show such clusters (Greenberg 1978).

following syllable, it remains as a stop, without the application of spirantization. To capture this pattern, Hahn (1998) proposes the following constraint:

(8) *LENI(-cont)]σ: stops in syllable final position are banned (i.e. do not associate [-cont] in the lenition context).

The constraint in (8) accounts for the occurrence of palatal fricatives rather than stops. Stops in syllable codas are not preferred in the syllabification process; thus, they are spirantized to fricatives or resyllabified as onsets of the following syllable.

Finally, stops in syllable codas are likely to be changed to more sonorous segments. These cases are also frequently discussed in the previous analyses proposing sonority principles. Stops in syllable codas are changed to vowels through "coda weakening" as in Klingenheben's Law in Hausa (Newman 1994) or through metathesis as in Sidamo (Vennemann 1988 : 55).

(9) a. coda weakening: Hausa

Old Hausa	Hausa	
ɓak.na	ɓau.na	'buffalo'
hag.ni	hau.ni	'left'
hak.rē	hau.rē	'tusk'

(Newman 1994)

b. metathesis: Sidamo

underlying	surface	
gud + nónni	gun.dónni	'they finished'
hab + némmo	ham.bémmo	'we forgot'
duk + nánni	duŋ.kánni	'they carry'
has + némmo	han.sémmo	'we look for'

(Vennemann 1988 : 55)

As is clearly shown in the examples in (9), stops are not allowed in syllable codas, and are thus changed to more sonorous segments such as vowels or nasals. Also it can be noted that even though only one example is shown above, the fricative /s/ in the coda position as in /has + nemmo/ 'we look for' is changed to a more salient alveolar nasal [n] as in [han.semmo].

The three cases discussed so far show that in syllable codas, stops, but

not fricatives or nasals, are easily deleted as in (6); otherwise, stops are changed to fricatives as in (7) or they are changed to more sonorous nasals or vowels as in (9). Also fricatives are changed to more salient nasals as in (9). These three different kinds of phonological processes can be uniformly explained in terms of saliency ranking, without any stipulative constraint. In the less prominent prosodic position, less salient consonants such as stops and fricatives are not or are less permitted. Rather more salient consonants are chosen to maintain their contrast. This is a strategy to maximize phonological contrast.

4. Acoustic Explanation for the Weak Salience of Stops

In this section, I show that segments which are prohibited or less frequently appear in syllable codas have a phonetic explanation. A closer look at the acoustic properties of various types of segments such as stops, fricatives, nasals, liquids, and glides can indeed provide a straightforward account of the contrastive behavior of these segments with respect to the permissibility for syllable codas.

Every consonant is composed of the closure and the release. The closure in stops, however, is totally silent; it cannot provide any kind of acoustic information about the characteristics of the segments. Thus the stop sounds convey their qualities by their effects on adjacent vowels. The transition from the preceding vowel through the stops as well as the release part contain formant cues. These cases are characteristic of the stops themselves and their place of articulations. In this sense these formant transitions are crucial for the stop distinction. However, if stops are not flanked by vowels, the cues for the identification of stops cannot be provided. More specifically, when the stops occur before pauses or heterosyllabic consonants, they contain very few cues that would allow them to be identified. In these cases, even the burst of the consonant is typically absent. Thus stops in syllable codas are hard to be distinguished or even identified.[5]

[5] An anonymous reviewer pointed out that even the silence of stops can be a cue for distinguishing them from other segments, since only stops are associated with silence, while other types of consonants show formant transitions or a considerable amount of noise. However, as he/she pointed out, the silence cannot provide a cue for the place of articulation in consonants, and more importantly, even in the manner of articulation, it cannot provide a cue whether the silence represents stops or just

On the other hand, nasals, liquids, and glides are characterized acoustically by their own formant transitions, even though less clear than the formants of vowels. The production of liquids and glides is articulated with an open vocal tract, which produces continuous acoustic signal. Nasals involve a complete closure in the oral cavity, but the airflow goes through the nasal cavity. As a result, nasals produce continuous acoustic signals. Thus in these types of sounds, flankness of vowels is not necessary for the identification of these sounds. Even though these sounds occur in word-final positions, or before heterosyllabic consonants, their own formant structures provide sufficient information about cues to allow them to be identified.

Fricatives can also be identified without formant transitions. These sounds display little or nothing like the sort of formant structures observed in nasals, liquids, or glides. However, fricatives produce a significant amount of noise during the closure of the consonants, though the frequency and the intensity of noise are different depending on the fricative sounds. The presence of audible noise in fricatives makes it possible for the sounds to be identified.

Overall nasals, liquids, glides and even fricatives contain acoustic cues even if they are not flanked by vowels, but stops are totally dependent on adjacent vowels. Therefore nasals, liquids, glides and fricatives are acoustically more "salient" than stops in syllable codas.[6]

5. Conclusion

The choice of more sonorous segments in syllable codas found in many languages may be a consequence of contrast maintenance. The syllable coda position is a linguistically less prominent position (Beckman 1997), and thus certain kinds of sounds such as stops (and less frequently fricatives) are not distinctive in this position, while the onset position is a strong enough to convey almost any kind of feature. This leads to the fact that stops in syllable codas are likely to be deleted or neutralized. To prohibit the deletion or neutralization of stops, much more salient - sonorous -

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pauses. Only under the condition that the relevant segments are consonants, silence can be a cue.

[6] As for the spectrograms and waveforms of each type of segment, see Borden, Harris and Raphael (1994 : 116-133); Hardcastle and Laver (1997 : 65-115).

segments are chosen for codas in the syllabification process.

This is a functional approach, based on the hypothesis that a major goal of a language is effective communication. To pursue a language's communicative function, native speakers should maximize the phonological contrasts to perceive the contrasts easily. This paper presents such functional goal's effect on the syllable structure constraints.

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