Interrelation Between Onset Cluster Sequences and the Sonority Hierarchy in English

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1. Introduction

In general, there is a strong tendency in syllable structure that the most sonorous segment, typically a vowel is placed in nucleus position, preceding and following less sonorous segments, which are arranged in order gradually less sonorous to the edge of the syllable. This tendency is widely known as the "Sonority Sequencing Generalization (henceforth, the SSG)" proposed by Selkirk (1984), and supported by many phonologists.

The SSG is a basic concept of syllable structure in many languages. According to this generalization, in a consonant cluster C_1C_2, the sonority of C_1 should be equal to or lower than that of C_2 in an onset ($C_1 \leqq C_2$), and in a coda, vice versa. This paper considers onset clusters in English, which mainly follow the SSG but also present a large class of apparent counter-examples to the generalization. In English, onset clusters mainly follow the SSG such as /pl/ as in *play*, /dw/ as in *dwell*, /kr/ as in *crown*, /fl/ as in *fly*, /sm/ as in *small* in a syllable. But on the contrary, there are quite a few examples that do not follow the SSG, containing /s/ as the first segment of an onset cluster, such as /sp/ as in *space*, /st/ as in *stay*, /sk/ as in *sky*, /spr/ as in *spray*, /str/ as in *street*, /skr/ as in *screen*. Since these are abundant in English, and cannot be removed as trivial exceptions, they are typical counterexamples to the SSG (Kubozono & Honma 2002:10f., 118).

Honma (2007) claims that there are some crucial problems for a syllable theory based on the sonority hierarchy analyzing phonotactic behavior of semivowels especially in English onsets. In this paper, I agree with Honma's (2007) proposal, and re-interpret the interrelation between syllable structure and the sonority hierarchy in English. Selkrik's (1984) SSG has wide cross-linguistic applicability, so it is desirable to preserve it if possible. Here, I argue that it can be preserved; what needs to be modified is the formulation of the sonority hierarchy, not the SSG itself.

In this paper, I propose mainly the following two points:

[1] to define the sonority hierarchy for the SSG as it pertains to English onsets solely in terms of the [voice] feature

[2] to draw a sharp line between the voiced feature of sonorants and glides without any voiceless counterparts and that of obstruents which have voiced/voiceless contrasts, at least as pertains to the SSG in English

This discussion is restricted to onset clusters in English. I leave the discussion of coda clusters to future work. Onset cluster ordering in English can be systematically compared with the data in Khmer (Kuwamoto 2012) or another kind of phenomena with nasals in Swahili (Kuwamoto & Miyamoto 2012), crosslinguistically. These are discussed in 6. and 7. below.

2. The distribution of English onset clusters

Roach (2009:56ff.) divides English double consonant clusters in an onset position into two patterns; i) those with initialized /s/ (ie. /sC/), and ii) those ending a liquid (/l/ or /r/) or a glide (/w/ or /j/). According to Roach (2009), both patterns are exclusively independent of each other, though initial /s/ (group i) plus following /l, r, w, j/ (group ii) really exist simultaneously as in; *slow*, *switch*, and *pursue*. (See note 1 and 2). As for the group i), Roach (2009) calls the initialized /s/ in /sC/ (/C/ is neither a liquid nor a glide) "pre-initial consonant," and the following /C/ "initial consonant[1])." The six possible /sC/ clusters are shown in (1).

(1) Two-consonant clusters with pre-initial s (Roach 2009:58, partly revised)

	Pre-initial	Initial						
			stop			fricative	nasal	
	s	+	p	t	k	f	m	n
examples			spɪn	stɪk	skɪn	sfɪə	smel	snəʊ

The range of variation of clusters belonging to group ii), all ending a liquid /l/ or /r/ or a glide /w/ or /j/ is shown in (2). The first segment in this kind of cluster can be anything including /s/[2]). This is called the "initial consonant," and the second segment, "post-initial."

(2) Two-consonant clusters with post-initial l, r, w j (Roach 2009:58, partly revised)

		Initial														
		voiceless stop			voiced stop			voiceless fricative					v-ed fri.	nasal		lat.
		p	t	k	b	d	g	f	θ	s	ʃ	h	v	m	n	l
Post-initial	l	pleɪ	×	kleɪ	blæk	×	glu:	flaɪ	×	slɪp	×	×	×	×	×	×
	r	preɪ	treɪ	kraɪ	brɪŋ	drɪp	grɪn	fraɪ	θrəʊ	?	ʃru:	×	×	×	×	×
	w	×	twɪn	kwɪk	×	dwel	?	×	θwɔ:t	swɪm	?	×	×	×	×	×
	j	pjɔ:	tju:n	kju:	bju:ti	dju:	?	fju:	?	sju:	×	hju:ʤ	vju:	mju:z	nju:z	lju:d

As for triple consonant clusters, the distribution is far more limited. The first segment must be /s/ belonging to pre-initial, and the last segment must be a liquid /l, r/ or a glide /w, j/. Triple consonant clusters in English are formed as in (3) in terms of Roach (2009).

(3) The structure of triple consonant onset clusters in English

pre-initial — initial — post-initial

The distribution of triple consonant onset clusters is shown in (4).

(4) Triple consonant clusters (Roach 2009:57)

			Post-initial			
			l	r	w	j
s + (Pre-initial)	Initial	p	'splay'	'spray'	×	'spew'
		t	×	'string'	×	'stew'
		k	'sclerosis'	'screen'	'squeak'	'skewer'

The data shown in (1), (2) and (4) are all the combinations of onset clusters in English. In the next section I show the interrelation between syllable structure and the sonority hierarchy in some previous studies, and analyze all the variants of onset clusters in English.

3. Selkirk's (1984) Sonority Sequencing Generalization

Selkirk (1984) points out that syllables in general conform to the SSG.

(5) Sonority Sequencing Generalization (SSG, Selkirk 1984:116)

> In any syllable, there is a segment constituting a sonority peak that is preceded and/or followed by a sequence of segments with progressively decreasing sonority values.

Preceding this proposal, Selkirk (1984) shows a hypothesis about sonority indices of segments. According to the hypothesis, each segment has its own sonority value, and a difference of values between any two segments shows sonority rising or falling. The following shows the sonority indices of some segments.

(6) Sonority indices (Selkirk 1984:112)

p, t, k	b, d, g	f, θ	v, z, ð	s	m, n	l	r	i, u	e, o	a
0.5	1	2	3	4	5	6	7	8	9	10

Kawagoe (1999) introduces a similar map of sonority indices to Selkirk (1984). Kawagoe (1999) simplifies and revises somewhat Selkirk's (1984) model for learners of English phonetics.

(7) Sonority indices (Kawagoe 1999:92)

voiceless stops	<	voiced stops	<	v-less fricatives	<	v-ed fric.	<	nasals	<	liquids	<	glides	<	vowels
1		2		3		4		5		6		7		8

In contrast, Kubozono & Honma (2002) suggests a slightly complicated model than Selkirk's (1984), including affricatives /ʧ, ʤ/ and diphthongs /ey, ow, ɔy, etc./ as targeting segments. This is based on Giegerich's (1992:133) sonority scale.

(8) Sonority scale (Kubozono & Honma 2002:114)

voiceless stops /p, t, k/ < voiced stops /b, d, g/

< v-less fricatives and affricatives /f, θ, s, ʃ, ʧ/ < v-ed fric. and affric. /v, ð, z, ʒ, ʤ/

< nasals /m, n, ŋ/ < liquids /l, r/ < glides /y, w/

< high vowels /iy, ɪ, uw, ʊ/ < mid vowels /ey, ɛ, ʌ, ə, ɔ, ow, ɔy/ < low vowels /ay, aw, æ, ɑ/

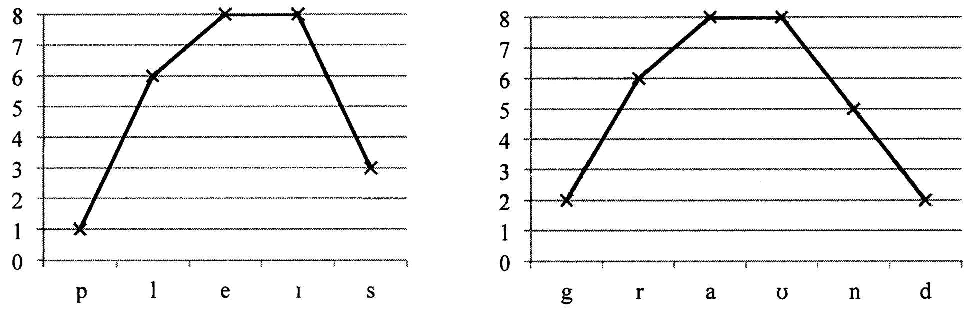
Kenstowicz's (1994) model is far more simple; there is no difference in sonority between stops and fricatives. Both of them merge into the single category of "obstruents."

(9) Sonority Sequencing Principle (Kenstowicz 1994:254[3])

obstruents < nasals < liquids < glides < vowels

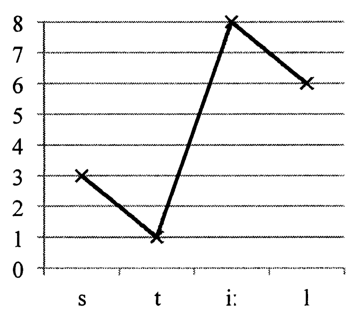
English onset clusters are expected to be ordered following the SSG. Typically, English onset clusters are ordered according to a map such as (6), (7), (8), or (9). (10a, b)[4)] show a schematization of two English words according to Kawagoe's (1999:93) ordering.

(10) a. "place" b. "ground"



In both examples, the nucleus of the syllable forms a sonority peak, with gradually decreasing sonority values forward and backward. On the other hand, /sC/ onset clusters like in "steel" don't form a steep rise in sonority. This is shown in (11).

(11) "steel"



This data is in fact a typical counterexample for the SSG. Though the SSG accounts for many phenomena in many languages, apparent counterexamples such as (11) are highly abundant in English. Thus /sC/ onset clusters are quite problematic for SSG based theories of syllable structure. In the next and later sections I discuss a re-interpretation of the sonority hierarchy and the relationship between a new version of the sonority hierarchy and syllable structure.

4. The sonority hierarchy based on the [voice] feature

Focusing on the voiced/voiceless features, a voiced segment has higher sonority than a voiceless segment regardless of its manner of articulation. Rather more sonorous segments such as vowels, glides, liquids, and nasals are all voiced segments. They are all ranged to the right side in the maps (7) or (8). On the other hand, voiceless segments cluster toward the left in (7) and (8).[5)] Approximately, the maps in (7) and (8) are revised to (12), based on voicing features.

(12) Revised version of the sonority hierarchy based on the [voice] feature.

voiceless segments < voiced segments

Following the sonority hierarchy in (12), in an onset cluster C_1C_2 both segments might have the same voice value, that is, C_1 and C_2 are both voiceless or voiced segments, or, simultaneously, C_1 is voiceless and C_2 is voiced. Looking back to the English cluster in (1) - (2) and (4), all the double consonant clusters C_1C_2 follow the order $C_1 \leqq C_2$ based on the voicing criterion, and as do the triple consonant clusters $C_1C_2C_3$, ($C_1 \leqq C_2 \leqq C_3$). So the hierarchy in (12) covers precisely all the patterns of onset clusters including the major counterexamples against the original sonority hierarchy i.e. /sC/ sequences (/sp/ in *space*, /st/ in *steel*, or /sk/ in *sky*).

The only order of those described in previous models of the sonority hierarchy is shown in (13).

(13) voiced stops < voiceless fricatives and affricatives

This order is included in Kawagoe's (1999) map as in (7) or Kubozono & Honma's (2002) as in (8). However, there is no such onset cluster following (13)'s order as in (14), so, at least in English, ignoring (13) can be rather appropriate for adopting the voice based sonority hierarchy.

(14) $_\sigma$[voiced stops— voiceless fricatives and affricatives

ex.: /*bs, *dθ, *gf, .../

Therefore, at least in English, the works cited in Kawagoe (1999) and Kubozono & Honma (2002) are not be incompatible with the revised voice based sonority hierarchy.

5. Interrelation between the [voice] feature and syllable structure

According to Roach (2000), (1), (2) and (4) provide a comprehensive listing of English onset structure mentioned in section 2. Focusing on the last segment, i.e. the position next to a nucleus of a syllable including it, there are many sonorant segments allowed. For example, all patterns in (1) and (2) end with the most sonorant, and the second most sonorant non-vowel segments: glides /w, j/ and liquids /l, r/. There are 47 onset cluster patterns in English in (1), (2), and (4); 6 in (1), 32 in (2), and 9 in (4). These 47 patterns are classified by the last segment of the onset clusters in (15).

(15)

a. ending with a glide /w, j/ (21 patterns):	/tw, kw, dw, θw, sw, skw, pj, tj, kj, bj, dj, fj, sj, hj, vj, mj, nj, lj, spj, stj, skj/
b. ending with a liquid /l, r/ (20 patterns):	/pl, kl, bl, gl, fl, sl, spl, skl, pr, tr, kr, br, dr, gr, fr, θr, ʃr, spr, str, skr/
c. ending with a nasal /m, n/ (2 patterns):	/sm, sn/
d. ending with a fricative (1 pattern):	/sf/
e. ending with a stop (3 patterns):	/sp, st, sk/

In (15), the second segments in the three classes (a-c) are rather more sonorous segments and all are so called "sonorants." The patterns in (15a-c) occupy a large majority of all the patterns. There are 43 patterns in all; glides: 21, liquids:20, nasals:2, out of 47 (43/47=91.5%).

Glides, liquids, and nasals are all classified as "voiced" segments. The predominance of sonorants as the last segment of an onset cluster strongly supports the revised version of the sonority hierarchy based on the [voice] feature shown in (12), because the order of "a voiceless segment ≦ a voiced segment" leads to a tendency that voiced segments are likely to be arranged in the position next to the nucleus. If the last segment of an onset cluster is a sonorant or a glide, the segment preceding it in the syllable can be any segment regardless of the [voice] feature, following the revised sonority hierarchy.

On the other hand, curiously enough, voiced obstruents such as /b, d, g, v, ð, z, ʒ/ cannot be the last segments of an onset cluster in English.

(16) /*sb, *zd, *bg, *sv, *sð, *bz, *fʒ, .../

A crucial observation here is that, in English, voiced obstruents have voiceless counterparts while "voiced" sonorants do not. Consonant sequences like in (16), if they are in an onset position, would properly follow the voice based sonority hierarchy. The onsets in (17) and (18) are also consistent with Selkirk's (1984) SSG (given proposed sonority hierarchies), but these are not found in English.

(17) voiceless stop — voiced stop sequences:

/*pb, *pd, *pg, *tb, *td, *tg, *kb, *kd, *kg/

(18) voiceless stop/fricative — voiced fricative sequences:

/*pv, *pð, *pz, *pʒ, *tv, *tð, *tz, *tʒ, *kv[6], *kð, *kz, *kʒ/

In this way, the distribution of sonorants or glides as the second segment is quite different from that of voiced obstruents although both are the types of voiced segments. Therefore I should make a clear line between them as regards syllable structure.

As for the first segment in an onset cluster, sonorants are rarely in this position while voiced obstruents can be, as in (19).

(19) /bl/ in *black*
/dr/ in *dream*
/gl/ in *glass*
/bj/ in *beauty*
/dw/ in *dwell*
:

On the other hand, as for the first sonorant, there are only three patterns as in (20).

(20) /mj/ in *muse*
/nj/ in *new*
/lj/ in *lewd*[7]

The patterns in (20) have only /j/ as the second segment. Honma (2007) claims that an onglide /j/ is considered to be part of the nucleus, not the onset[8]. According to Honma (2007), it follows that there aren't originally any onset clusters with a sonorant as the first segment. In the same way, the only pattern of an onset cluster with a voiced fricative as the first segment /vj/ as in *view* shouldn't be considered as an onset cluster. As a result, the voiced segments which are permitted as the first segment in an onset cluster are limited to stops.

From the discussion above, I conclude that the [voice] feature is deeply correlated with the sonority hierarchy or syllable structure itself, and the [voice] feature in sonorants or glides, which don't have their voiceless counterparts, should be clearly divided from that in obstruents with voiceless/voiced contrast.

In the next two sections I introduce previous studies about sonority and syllable structure in other two languages, one is Khmer, spoken in Cambodia in Continental Southeast Asia (Kuwamoto 2012), and the other is Swahili spoken in East Africa and used as a lingua franca widely in Central and East Africa (Kuwamoto & Miyamoto 2012). Although the areas where each of the two languages are spoken are situated far from English speaking areas, and although both languages belong to quite different language families, the behaviors of the [voice] feature or some phenomena including voiced obstruents or sonorants are quite similar to those of English, and the patterns found in these languages lend support to the analysis in this paper.

6. Onset clusters in Khmer

In Khmer there are many onset clusters. Kuwamoto (2012) analyzes 84 patterns of Khmer onset clusters in total, all of which are double consonant clusters[9]. Out of 84 patterns, sonority falling occurs in 19 patterns (22.6% to the whole 84 patterns), violating Selkirk's (1984) SSG. These are shown in (21).

(21) 19 patterns of sonority falling onset clusters in Khmer (Kuwamoto 2012:22f.)

a. /sC/	6 patterns		
	/sp/	in spi·ən	'bridge'
	/st/	in stu:c	'lift'
	/sk/	in skɔ:	'sugar'
	/sʔ/	in sʔaək	'tomorrow'
	/sb/	in sbaek	'skin'
	/sd/	in sdam	'right (side)'
b. /mC/	5 patterns		
	/mt/	in mtè:h	'red pepper'
	/mc/	in mcah	'master'
	/md/	in mda:i	'mother'
	/ms/	in msəl məɲ	'yesterday'
	/mh/	in mho:p	'dish'

c. /lC/ 8 patterns

/lp/	in lpə̀w	'pumpkin'
/lk/	in lkɔ̀:i	'elegant'
/lʔ/	in lʔɔ:	'good'
/lb/	in lbəi	'famous'
/lm/	in lmɔ̀:m	'sufficient'
/lŋ/	in lŋi·əc	'evening'
/lv/	in lvi·ə	'fig'
/lh/	in lhoŋ	'papaya'

If the revised sonority hierarchy based on the [voice] feature in (12) above mentioned is adopted in the counterexample patterns in (21), the patterns violating the SSG are reduced to the 8 shown in (22).

(22) 8 patterns violating the revised sonority hierarchy (Kuwamoto 2012:24)

/mC/:	/mt, mc, ms, mh/	4 patterns
/lC/:	/lp, lk, lʔ, lh/	4 patterns

8 patterns constitutes 9.5 % out of the whole (84 patterns: 8/84=9.5). Though a few exceptions remain in Khmer onset clusters, an adaptation of the voice based sonority hierarchy, suggested in Kuwamoto (2012) and also in this paper, is reasonably effective for Khmer as well as English. But the remaining 8 patterns in (22) are still problematic, for sonorants are the first segments of onset clusters, which is precisely prohibited in English onsets.

7. Syllabification of /NC/ sequences in Swahili

As for Swahili's /NC/ sequences, they follow two kinds of syllabification. One is a homosyllablic formation as an onset cluster, and the other is a heterosyllabic formation, where a preceding nasal forms a syllable in itself, so becomes a syllabic nasal, and a following consonant, usually, an obstruent, becomes an single onset. In Kuwamoto & Miyamoto (2012), we analyze two kinds of syllabification in terms of the [voice] feature, and suggest that, if C is voiced, then the [voice] feature in it harmonizes with the [voice] feature in the preceding nasal, and the /NC/ becomes an onset cluster, but if C is voiceless, then the difference of voice triggers a heterosyllabic analysis of /N/ as a syllabic nasal on one hand, and the following /C/ as a single onset on the other.

(23) two kinds of syllabification of /NC/ sequences in Swahili (Kuwamoto & Miyamoto 2012)

a. Voiced C : $_{\sigma}[NC_{[+voice]}$

mba.li	'far'
ndi.yo	'yes'
mgo.mba	'banana tree'

b. Voiceless C: $_{\sigma}[N]_{\sigma}[C_{[-voice]}$

m.tu	'person'
m.pa.ka	'to, till'
n.chi	'country'

These phenomena also support a voice-related analysis in syllabification as well as English and Khmer onset clusters.

8. Conclusion

In this paper I overview onset clusters in English, and analyze them in relation to the sonority hierarchy. At a crosslinguistic level, Selkirk's (1984) SSG has been very successful in analyzing syllable structure in many languages. In spite of this crosslinguistic applicability, there remains a large number of counterexamples against the SSG, i.e. /sC/ sequences like /sp, st, sk, spr, str, skr,.../, which appear frequently in English data. To address these counterexamples, while preserving the SSG, I propose a revised version of the sonority hierarchy, whose relevant features are limited to the [voice] feature. Applying this concept, the sonority hierarchy is reduced to a voiceless < voiced order. According to the revised order, I can thoroughly explain English onset clusters following the sonority hierarchy.

Furthermore, through the analysis of onset clusters related to sonority, some biased distribution between two kinds of segments, sonorous segments, i.e. sonorants and glides, on one hand, and obstruents on the other is shown here. The bias of distribution is attributed to whether a voiced segment has its voiceless counterpart or not. Any voiced obstruents would have their voiceless counterparts, while sonorants and glides would not, at least in English. In summery, the [voice] feature is strongly related to syllable structure. Again the tight relationship between syllable structure and the [voice] feature is further supported by some of my previous studies on other languages.

Notes

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1) Initial consonants don't include liquids /l, r/ or glides /w, j/. They belong to "post-initial" (Roach 2009:57). In this context, pre-initial /s/ cannot coincide with "initial" liquids nor glides.

2) Since /s/ preceding /l, r, w, j/ as in *slow*, *switch*, or *pursue* is considered to belong to "initial consonants," not to "pre-initial," clusters with pre-initial /s/ are independent of those ending /l, r, w, j/. These two groups are distributed complementarily (Roach 2009:57ff.).

3) Kenstowicz claims that this kind of hierarchy is as yet unexplained by phonetic factors: "...a simple phonetic correlate to the phonological property of sonority has yet to be discovered,..." (Kenstowicz 1994:254)

4) Similar analyses can be found in Giegerich (1992:133ff.) and Kubozono & Honma (2002:115).

5) Kenstowicz's (1994) model in (9) is vague about the order of voiceless and voiced segments, for in (9) there is no difference between voiceless and voiced obstruents. In any case, Kenstowicz's (1994) model isn't incompatible with later discussions in this paper because Kenstowicz (1994) claims that the difference between voiceless and voiced features isn't related to sonority itself.

6) /kv/ is found, for example, in German: Qualität /kvalitɛ́:t/ *quality*.

7) /j/ in *lewd* /lju:d/ is inserted only in British accent. In American accent *lewd* is usually pronounced as /lu:d/.

8) See also Davis & Hammond (1995).

9) There are no triple consonant clusters in Khmer.

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英語における頭子音結合の序列と聞こえ度階層の相関について

桑本裕二

一般に、音節構造は、聞こえ度配列一般化（Sonority Sequencing Generalization; Selkirk 1984）に従い、たとえば頭子音結合 C_1C_2 において、C_1 の聞こえ度が C_2 より低くなるように配列されるが、英語には、“space” /speɪs/ のような反例がある。本稿では、通常用いられる調音様式に基づく聞こえ度階層を、有声性に特化してとらえ直し、音節先頭部の子音結合が「無声音—有声音」の序列に従うものと再解釈した場合、上記の反例も含め、英語の頭子音結合はほぼ例外なくこの基準に従っていることを示し、2 子音結合 C_1C_2 の後部要素 C_2 が半母音、流音、鼻音など、対立する無声音のない有声音である場合がほとんどであること、また、対立する無声音のある有声阻害音には、/*pv, *tb, *kð/ などの結合が許されないことから、有声性の対立のある／ない有声音を区別することが、英語の頭子音結合の分布にきわめて効果的であることを示した。

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